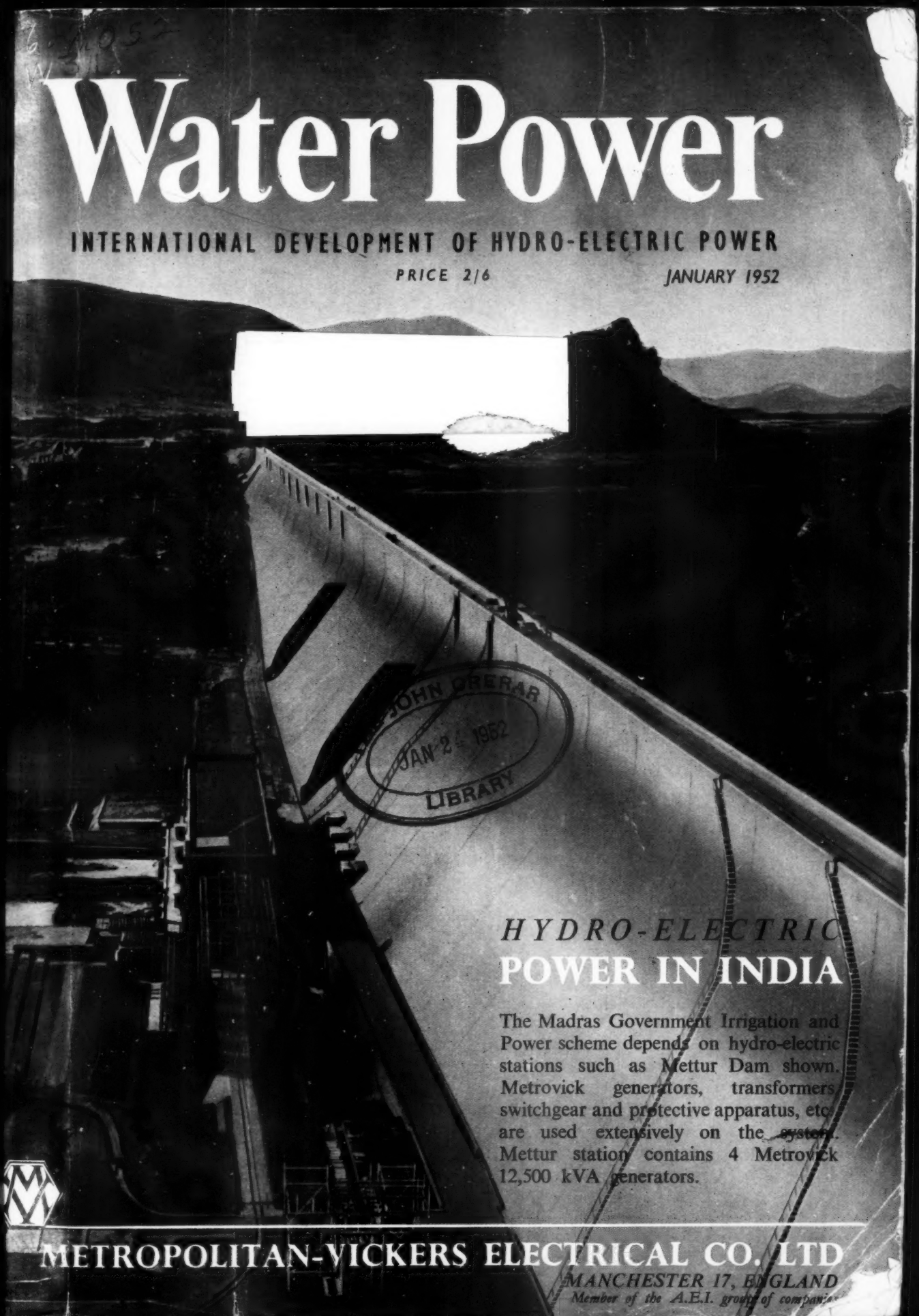
621.052
W35

Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

PRICE 2/6 JANUARY 1952

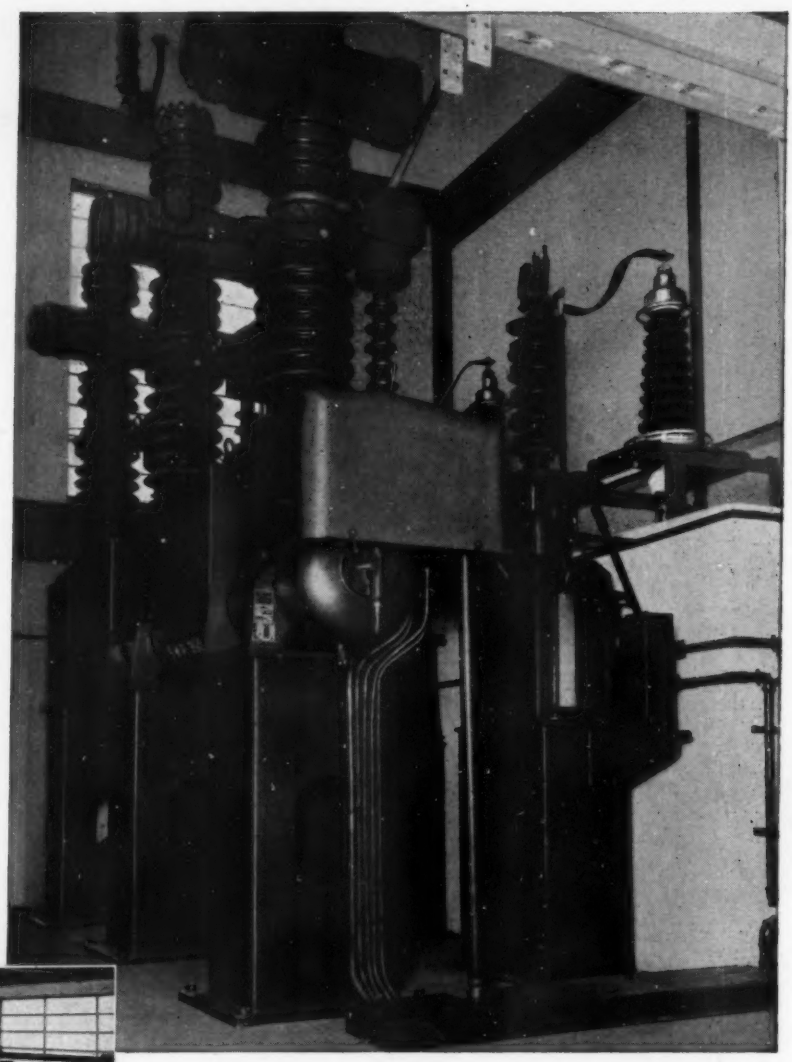


HYDRO-ELECTRIC POWER IN INDIA

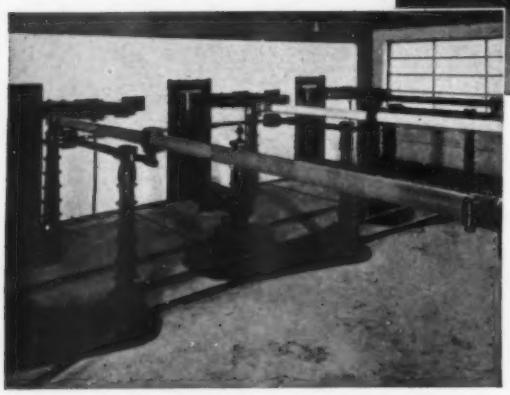
The Madras Government Irrigation and Power scheme depends on hydro-electric stations such as Mettur Dam shown. Metrovick generators, transformers, switchgear and protective apparatus, etc. are used extensively on the system. Mettur station contains 4 Metrovick 12,500 kVA generators.

METROPOLITAN-VICKERS ELECTRICAL CO. LTD
MANCHESTER 17, ENGLAND
Member of the A.E.I. group of companies

★ *If you want to talk switchgear . . . . talk to Reyrolle*



AIR-BLAST SWITCHGEAR AT NORTH TEES



The indoor installation of 66 kV air-blast switchgear at the North Tees Power Station of The British Electricity Authority (North Eastern Division) has circuit-breakers of 2500 MVA breaking capacity. There is a ring-busbar system in chambers above the circuit-breaker compartments. Each three-phase circuit-breaker, standing on a pedestal to give the necessary clearance, is mounted in a separate compartment, bushing-type isolators which are earthed in the open position are mounted in the compartment walls and allow safe access to equipment which has been isolated.

If you want to talk switchgear ... talk to Reyrolle

A. Reyrolle & Company Ltd., Hebburn, Co. Durham.

CRC 175

GLENFIELD

CONTROL VALVES

for Hydro-electric
Power Plants

The Anti-vacuum Valve

LOCATED at changes of gradient or immediately downstream of automatic self-closing valves in LARGE STEEL PIPELINES, TO OPEN AUTOMATICALLY on the formation of vacuum which may occur at change of load, when the pipeline is being drained, or in event of a burst, and thus by permitting the free inflow of air TO SAFEGUARD THE PIPELINE AGAINST COLLAPSE.

Glenfield
GLENFIELD & KENNEDY LIMITED KILMARNOCK

Head Office and Works:

KILMARNOCK, SCOTLAND

BOMBAY OFFICE:
9, WALLACE STREET. P.O BOX 443

CALCUTTA OFFICE:
FAIRLIE HOUSE, FAIRLIE PLACE
P.O. BOX 2115

Representatives in most countries

One of the 4 TRANSFORMERS

"Shell-Type"

OF 75 000 kVA, INTENDED FOR THE BELGIAN CENTERS OF INTERCONNECTION FOR NETWORKS OF 150/70kV.

75 000 kVA

3 WINDINGS : 150/70/10 kV.
ON LOAD VOLTAGE REGULATION : ± 17,5 % ON THE 150 kV SIDE
3 RANGES OF LOAD : 45 000 kVA - 60 000 kVA - 75 000 kVA according to the type of cooling system.

Ateliers de Constructions Electriques de Charleroi

CHARLEROI CAC/EC

Boving

The Waitaki power station is at present being extended with two BOVING-FRANCIS turbines. The station will then contain seven main turbines, all but the third and fourth being supplied by BOVING. The fabricated runner for one of these turbines is illustrated.

RATING	
Nett head	70 ft.
Output	23,000 b.h.p.
Speed	125 r.p.m.
Type	Vertical BOVING-FRANCIS
Diameter of runner	12.3 ft.

Boving
E COMPANY LIMITED

WATER POWER ENGINEERS

Head Office:
56, KINGSWAY, LONDON, W.C.2, ENGLAND

Branch Offices: Wellington: Druids Chambers, Woodward Street.
Melbourne: 99 Queen Street.
Calcutta: c/o Messrs. Macneill & Barry Ltd., 2 Fairlie Place.
Chittagong: (Pakistan.) c/o Messrs. Macneill & Barry Ltd., Strand Road.

B.C.11

Dominion Engineering

HYDRAULIC TURBINES

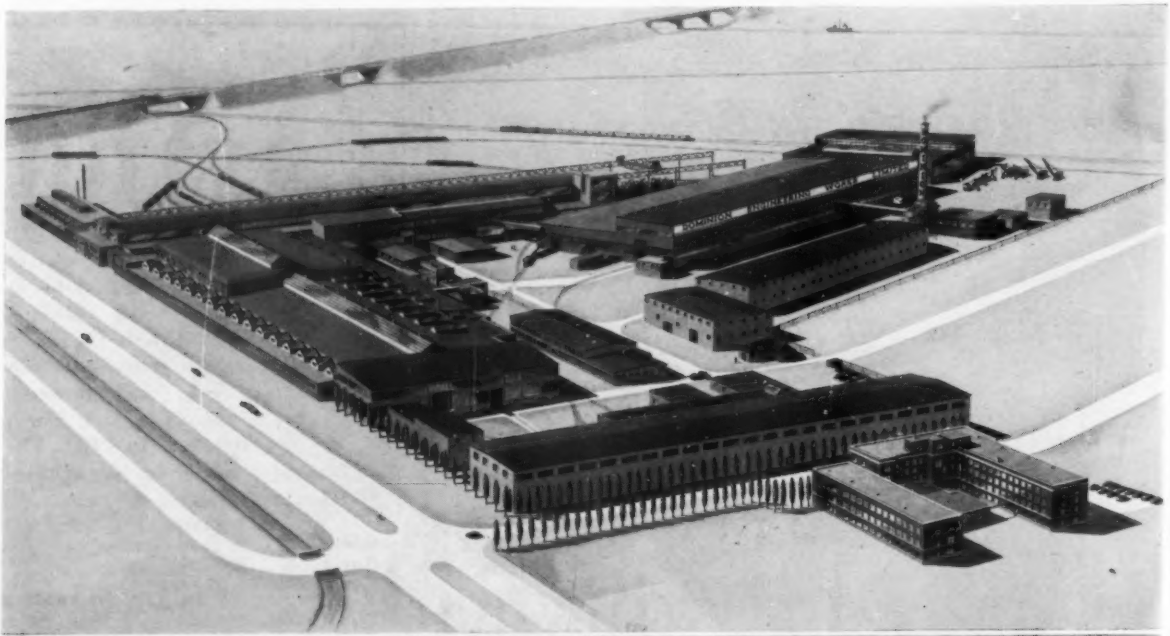
Water power has been a dominant factor in Canada's tremendous modern advance — and over half the water power developed in Canada has been harnessed by Dominion Engineering Hydraulic Turbines.

In Canada and abroad, the Francis, Propeller and Impulse Type Turbines already installed or now under construction at Dominion Engineering represents a total capacity of over 8,800,000 H.P.

The facilities and experience indicated by such a record are at your service anywhere in the world.

Write for General Bulletin No. 201 on Dominion Hydraulic Turbines.

Dominion Engineering Works at Montreal, Canada

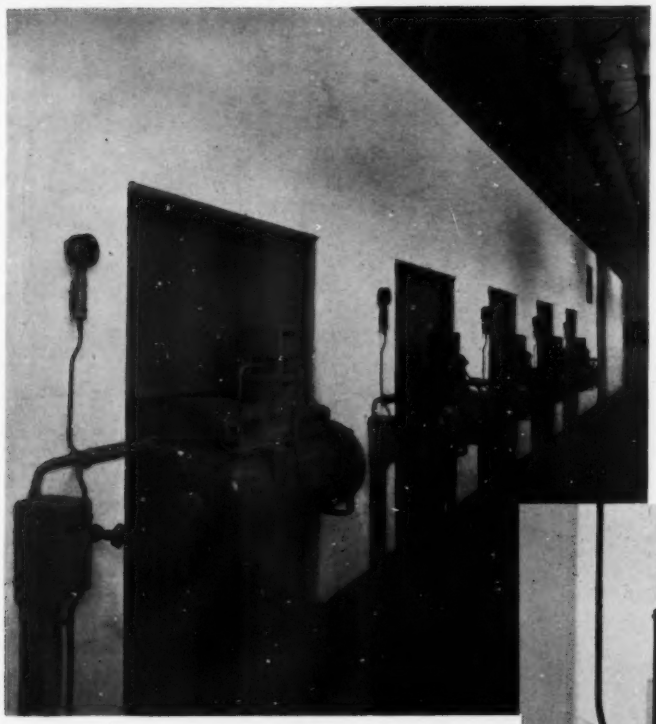


DOMINION ENGINEERING
COMPANY LIMITED

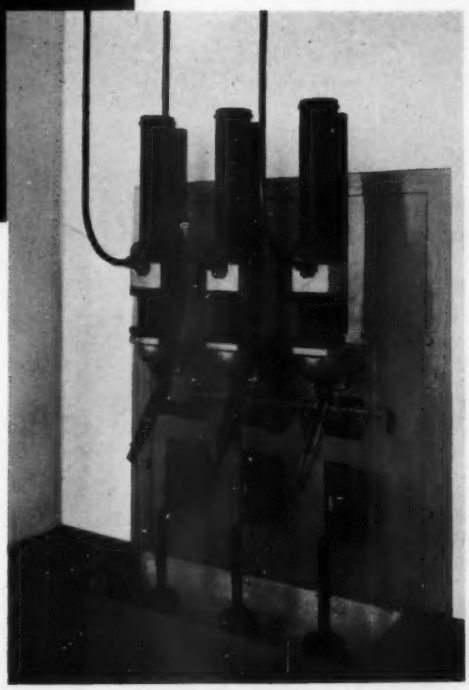
MONTREAL, CANADA — CABLE: DOMWORKS

BROWN BOVERI

AIR-BLAST HIGH-SPEED CIRCUIT-BREAKERS



Left-hand illustration: Air-blast high-speed circuit-breaker type DB for 20 kV, 1000 A, 1000 MVA, seen from the operating side. The high-voltage and operating sides are separated by a panel. Each circuit-breaker can be operated by hand from the inspection gangway. The position of the isolating switch is indicated mechanically.



Indoor-type air-blast high-speed circuit-breakers

up to 60 kV, 4000 A, and 2000 MVA

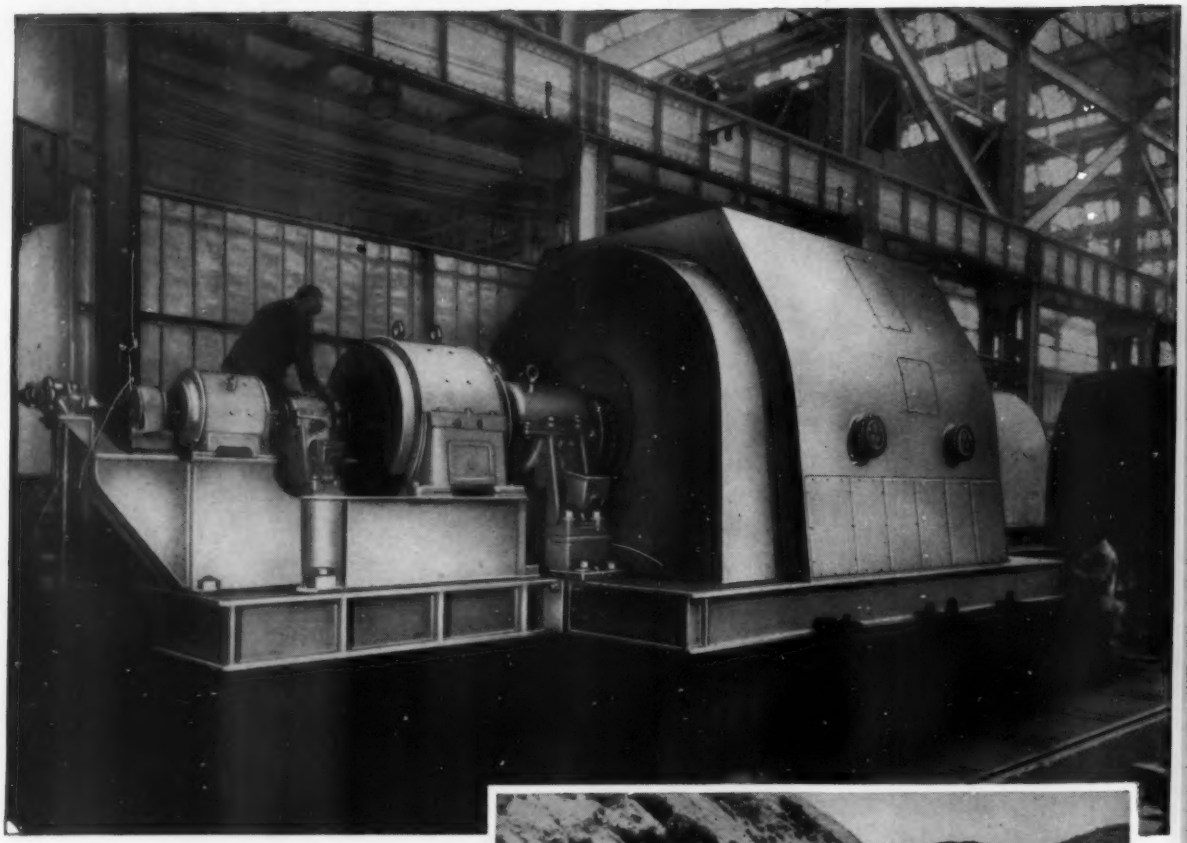
- **Oil-less**
- **Short break time**
- **High-speed reclosing**
- **Minimum contact erosion**
- **Always ready for service, even after heavy-duty interruptions**

Right-hand illustration: Same breaker as above, but seen from the high-voltage side. The simple arrangement of the conductors and visible position indication of the contacts can be clearly seen.

Over 10,000 air-blast high-speed circuit-breakers have been ordered to date, of which the greater number has been in service for many years past

BROWN, BOVERI & CO., LTD., BADEN (SWITZERLAND)

Hydro-electric Equipment



One of five 30,000 kVA., 750 r.p.m., 11,000 volt synchronous condensers supplied to the New Zealand State Hydro-electric Department. Two more are on order

Stator of one of the above condensers during its journey in New Zealand from the docks to site.

For all plant required for
Hydro-electric Power Schemes
— Consult BTH

BRITISH THOMSON-HOUSTON

THE BRITISH THOMSON-HOUSTON CO. LTD. RUGBY, ENGLAND

A3081

Member of the AEI group of companies

HIGH PRESSURE PIPE LINES FOR HYDRO-ELECTRIC POWER PLANTS

Design **Supply** **Erection**

RJUKAN HYDRO ELECTRIC POWER PLANT, NORWAY

The Pipe Lines shown above were Supplied and Erected by the FERRUM Organization

FERRUM (England) LIMITED, London, and their Associate Company, FERRUM MONTAGE A.S., Oslo, Norway, have for many years specialized in Design, Supply and Erection of High Pressure Pipe Lines for Hydro Electric Power Plants.

The accumulated experience gained by our Organization and our record of more than 300 Contracts for Supply of Pipe Lines to Hydro Electric Power Plants throughout all parts of the World enables us to offer unrivalled co-operation to ensure the installation of safe, efficient and economic High Pressure Pipe Lines.

Since the beginning of 1946 Contracts for the Supply and Erection of High Pressure Pipe Lines have been placed with our Organization for 43 separate Hydro Electric Installations, including highly important Power Plants in Norway, India, Tasmania and Australia. The total value of these Contracts exceeds £1,000,000.

FERRUM (England) Limited ENGINEERS

STAFFORD HOUSE, 43 NORFOLK STREET, LONDON, W.C.2

TARGET DATEA

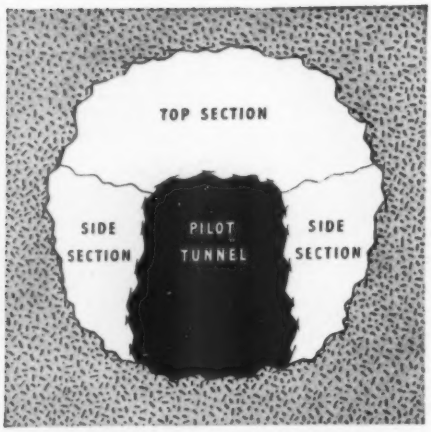


Fig 1 *A cross section of the Volturno tunnel (16 ft. 3 in. diam.) showing the rock face as divided into four areas for drilling and blasting.*

Record tunnel driving performa at the Volturno River hydro-elec plant in Italy—thanks to the Swed Method, adapted in this instance a type of rock which created unus drilling and blasting difficulties.

Hardly a we of excepti what is no Swedish M sting in that it thod for the ty he work was rs. A. Farsura c to convey wat dro-electric pl d'Evandro, C s long, with a d e rock was com haracter which g measures. he drills used w with pneumat nant Drill Steel these light drills pace was largel pid progress. A ermining speed romant Drill S be used almost (Even in the to Drill Steel will pe gauge or edge). lany drilling m consultants, an eer in charge o on a division of as shown in th ot tunnel driven eading. This w examination of ds in the main to facilitate m unnel enabled in before blasti ain heading. I g-out to take p nnel at the sam e whole train of y for the two ne he rate of progre d a record for tu ng days 15,210 f two faces: durin he figure was 29 y (29th Novemb e original targe nel was 31st Ma d on 12th Decer le! This vital sav of the Swedish

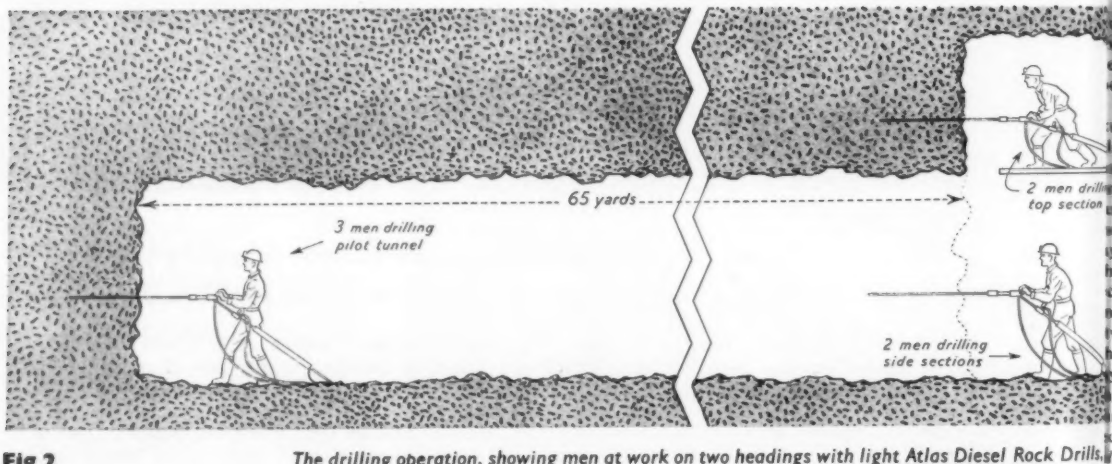


Fig 2 *The drilling operation, showing men at work on two headings with light Atlas Diesel Rock Drills with Sandvik Coromant Drill S*

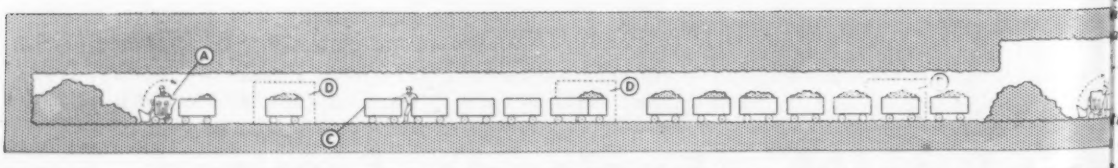


Fig 3 *Mucking-out took place in the main tunnel and the pilot tunnel simultaneously—an important in time saving. A and B show compressed air driven loaders at work; C is the train of 15 cars sh into the pilot tunnel prior to blasting, and D indicates the niches cut in the side of the tunnel to for cars to be side-tracked in order to load all 15 cars operating on a single t*

power station, Meridionale di annual productio

ture describing of the equipm out this Vouch Company Ltd., ional letterhead

EATEN BY FIVE MONTHS!

ardly a week passes without some new story of exceptional tunnelling performance by what is now known all over the world as the Swedish Method. This one, from Italy, is sting in that it concerns a special adaptation of thod for the type of rock encountered.

he work was executed by the Contractors, s. A. Farsura of Milan, and the tunnel was de- to convey water from the Volturno River to a dro-electric plant now nearing completion at d'Evandro, Campobasso.* It was just over long, with a diameter, before lining, of 16 ft., e rock was compact limestone of extremely vari- haracter which called for special drilling and g measures.

he drills used were light Atlas Diesel type RH- with pneumatic pushers, fitted with Sandvik nant Drill Steels. The ease and simplicity with these light drills are handled by one man in con- pace was largely responsible for the exception- pid progress. Another equally important factor rmining speed was, of course, the use of Sand- romant Drill Steels, which, in this type of rock, be used almost interminably without re-sharp- (Even in the toughest leptite a Sandvik Coro- Drill Steel will penetrate 50 feet before effectively gauge or edge).

lany drilling methods were discussed with the consultants, and after various tests the Chief eer in charge of the work, Signor Arrigoni, de- on a division of the rock face into three drilling as shown in the accompanying diagram, with t tunnel driven unusually far in advance of the eading. This was partly to allow for a more de- examination of the rock, and so adapt blasting es in the main heading during progress, and to facilitate mucking-out. The length of the unnel enabled a whole train of 15 cars to be in before blasting the top and side sections of ain heading. In this way it was possible for g-out to take place in the main tunnel and the unnel at the same time, the operation so timed e whole train of cars moved out together, mak- y for the two new gangs of drillers.

he rate of progress on the Volturno tunnel con- d a record for tunnels of this type. During 270 g days 15,210 feet of tunnel were accomplished two faces: during the week of 8-15th October he figure was 295 feet, and the highest figure for y (29th November) was 69 feet.

e original target date set for the completion of nel was 31st May 1951. The tunnel was actually d on 12th December 1950, *five months ahead of le!* This vital saving was only made possible by of the Swedish Method.

power station, now under construction for the Meridionale di Elettricità, Naples, is designed annual production of 137,000,000 kWh.

ure describing the Swedish Method with of the equipment used may be obtained by out this Voucher and posting it to the Atlas Company Ltd., attached to your business or ional letterheading.

AND YET ANOTHER...

BRITISH TUNNELLING RECORD BEATEN AT LOCH SLOY!

Yet another triumph for the Swedish Method—and this time the story comes from Scotland.

During the week ended Sunday, 10th June 1951 three gangs of ten men, using Atlas Rock Drills with pneumatic pushers and Sandvik Coromant Drill Steels and working 21 shifts of 8 hours each, drove 427 feet through hard diorite rock. How's that for productivity!

The tunnel is 7 ft. by 7 ft. and when completed will be 6,000 feet long. It forms a part of the North of Scotland Hydro-electric scheme, and the Contractors (to whom we are indebted for this picture of the team) are Edmund Nuttall, Sons & Co. (London) Ltd. This beats this company's previous record of 313 feet established three months earlier. Subject to confirmation, the figure of 427 feet is understood to be a new European tunnel driving record.

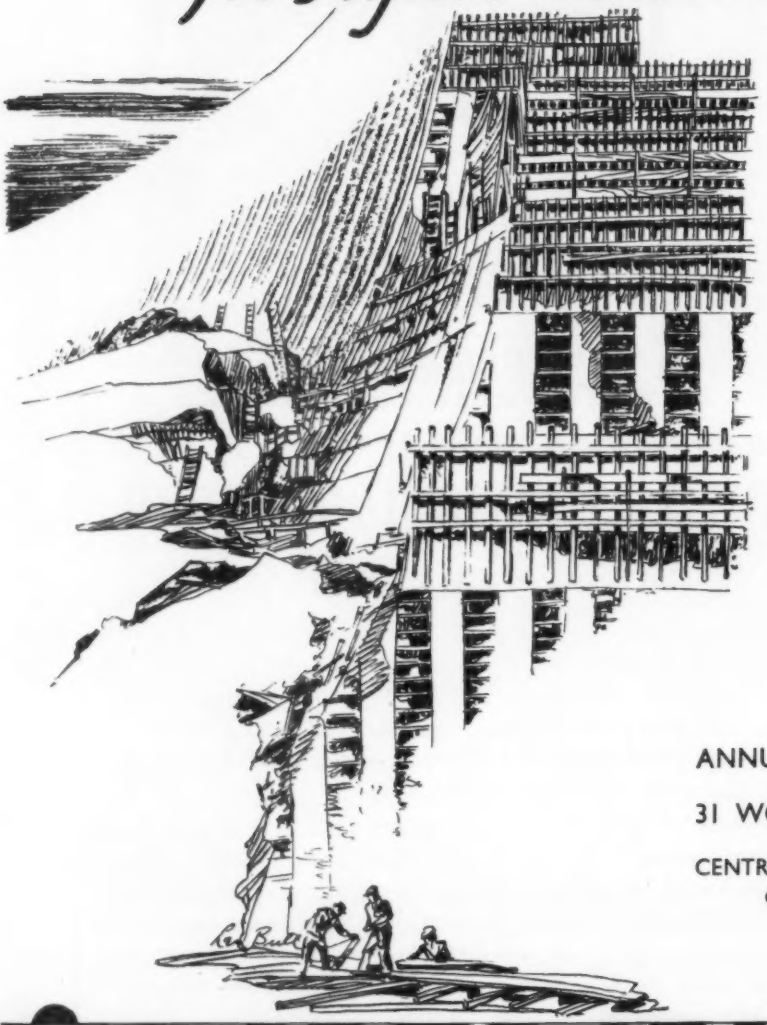
VOUCHER To ATLAS DIESEL COMPANY LTD · Beresford Avenue · Wembley · Middlesex

Please send us literature describing the Swedish Method, addressing it personally to:

Our business (or professional) letterheading is attached

Cement

for Hydro-electric schemes



Exporters to all parts of the World

Cement complying with BSS No. 12/1947

Special low heat cement for dams

White Cement. High early strength cement

Special pozzuolanic cement for sea works

•

ANNUAL CAPACITY 3,500,000 TONS

31 WORKS THROUGHOUT ITALY

CENTRAL LABORATORY FOR RESEARCH ON CEMENT & CONCRETE

ITALCEMENTI

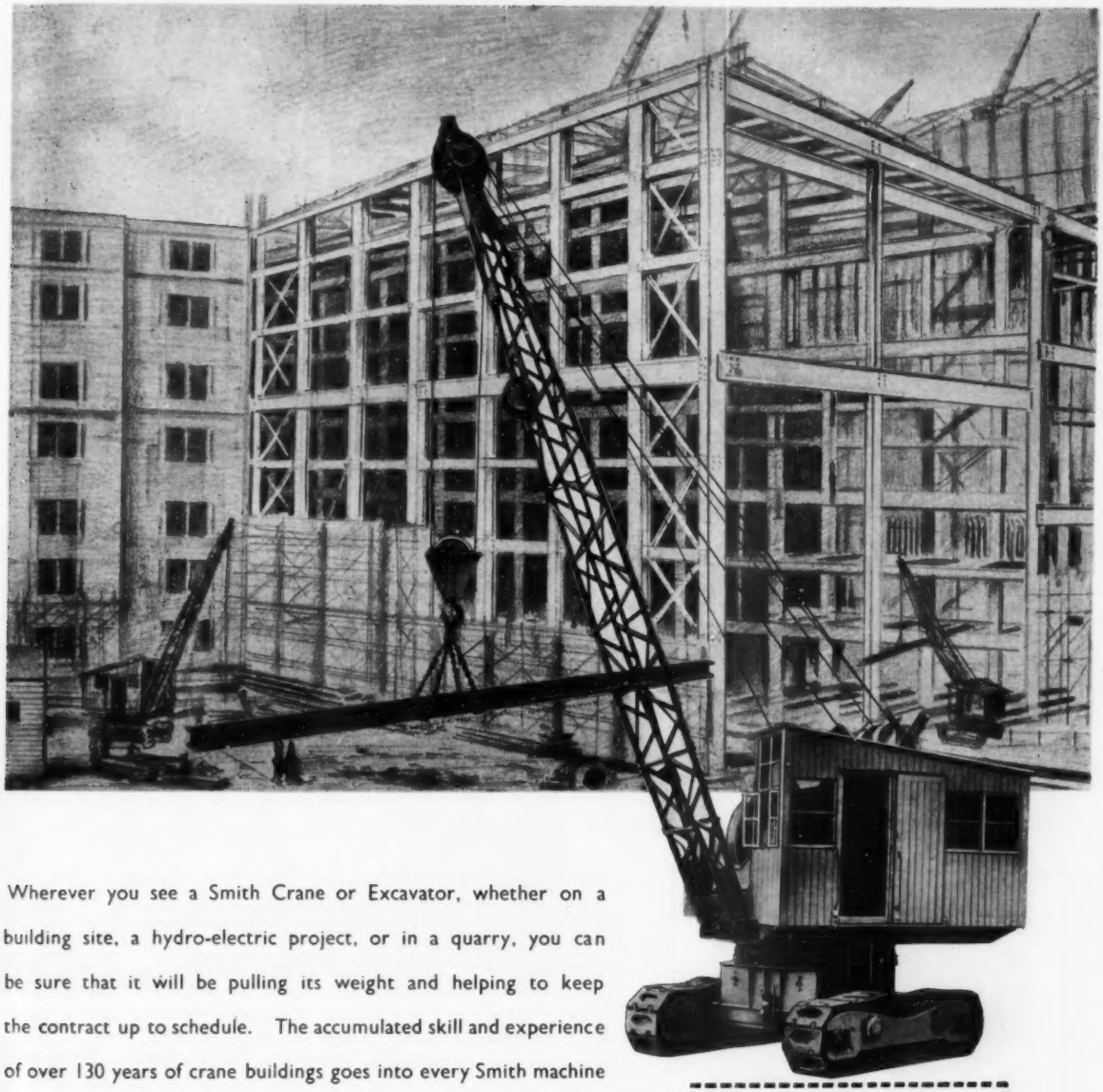
CAPITAL—ITALIAN LIRE 4,000,000,000

FABBRICHE RIUNITE CEMENTO

BERGAMO · ITALY

ADDRESS: "ITALCEMENTI," P.O.B. 247, BERGAMO (ITALY) · CABLES: ITALCEMENTI, BERGAMO

BACKGROUND OF EXPERIENCE



Wherever you see a Smith Crane or Excavator, whether on a building site, a hydro-electric project, or in a quarry, you can be sure that it will be pulling its weight and helping to keep the contract up to schedule. The accumulated skill and experience of over 130 years of crane buildings goes into every Smith machine and is reflected in sturdy design, high efficiency, and low running costs.

This 10-ton Diesel Crawler Crane which lifts 10 tons at 16ft. radius, can be fitted with any length of jib up to 80ft. centres, and can be arranged to operate an electric magnet or grab.

3039

THOMAS SMITH & SONS (RODLEY) LTD

Crane and Excavator Works Rodley Leeds

LIKE BRITAIN . . .

Canada chooses BRADY PATENTED

Brady shutters stand up to the most arduous climatic conditions—this is a Brady installation for Shipping Containers Ltd., in Montreal.

Efficient routine service, no less than enterprise, makes 'Brady' a by-word in Canada too. This gear-operated bank of four steel shutters was recently fitted for the Dominion Textile Company Ltd., of Montreal. A standard roller-shutter installation, it is just one example of everyday service by Brady abroad. There as in Britain, our organisation sets itself out to meet the normal and unusual roller-shutter specifications with equal efficiency.

We shutter the world

BRADY PATENTED

G. BRADY & CO. LTD · ANCOATS · MANCHESTER 4 · Phone: COLlyhurst 2797/8

LONDON: New Islington Works, Park Royal, N.W.10 · BIRMINGHAM: Rectory Park Road, Sheldon 26

CANADA: G. BRADY & CO. (CANADA) LTD. 1405 Bishop Street, MONTREAL 25.

Manufacturers of Brady Hand and Power Operated Lifts

S & B

If It's Hydraulics~
Put It Up to Us!

The SMITH *Impulse* Turbine

Value -- Plus! An impulse turbine with a simple solid cast runner. By casting the wheel in one piece, more buckets can be set closer to the hub than with the old orthodox design. Higher speeds with lower generator costs can thus be obtained. Other important features such as improved nozzle design, shape and fixation of the buckets and correct and proper baffling within the turbine housing, are also provided. Users are thus assured of smooth operation and higher efficiency. Full details in Bulletin 147. Send for your copy.

S·MORGAN SMITH COMPANY
YORK·PENNSYLVANIA~U·S·A·

POWER *by* SMITH

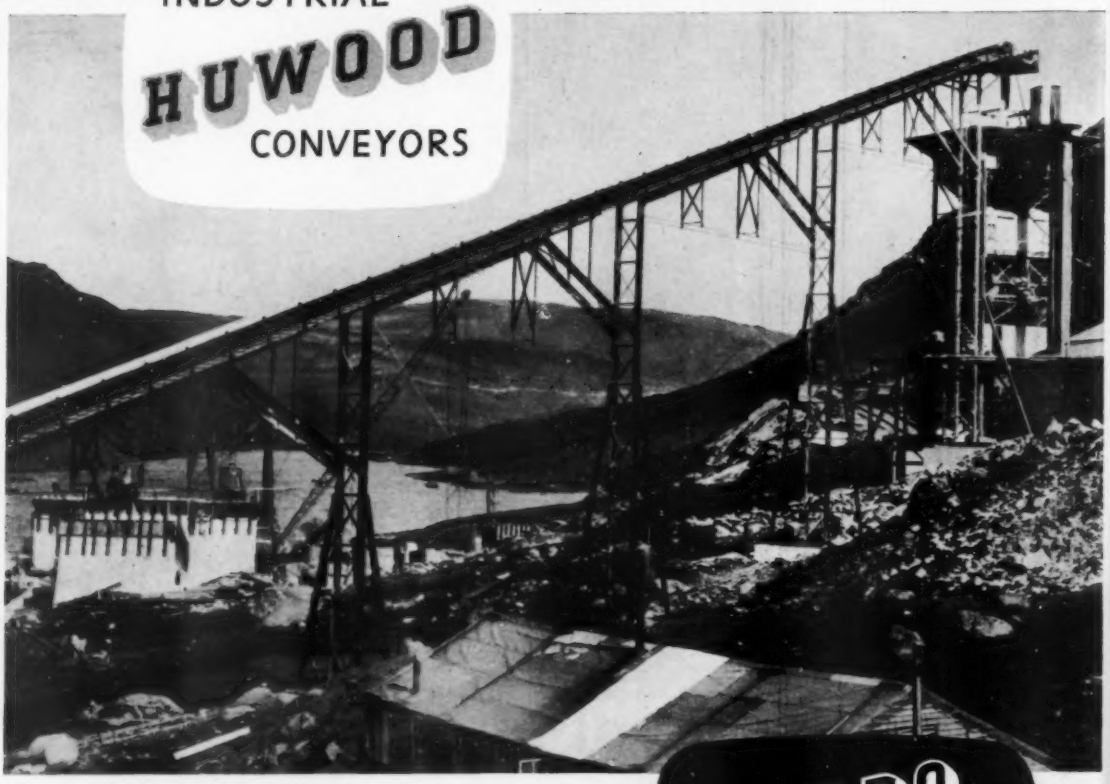
Quarry to Batching PLANT

STONE & AGGREGATE

INDUSTRIAL

HUWOOD

CONVEYORS



HYDRO ELECTRIC

SCOTLAND · TUMMEL GARRY · LOCH SLOY
ERROCHTY DAM

AFRICA · OWEN FALLS · UGANDA

INDIA · HIRAKUD DAM PROJECT

HUGH WOOD & CO. LTD.

HUWOOD

Head Office & Factories : GATESHEAD-ON-TYNE, 11

Industrial & Export Office : DASHWOOD HOUSE, 69, OLD BROAD STREET, LONDON, E.C.2

IND/120C/1

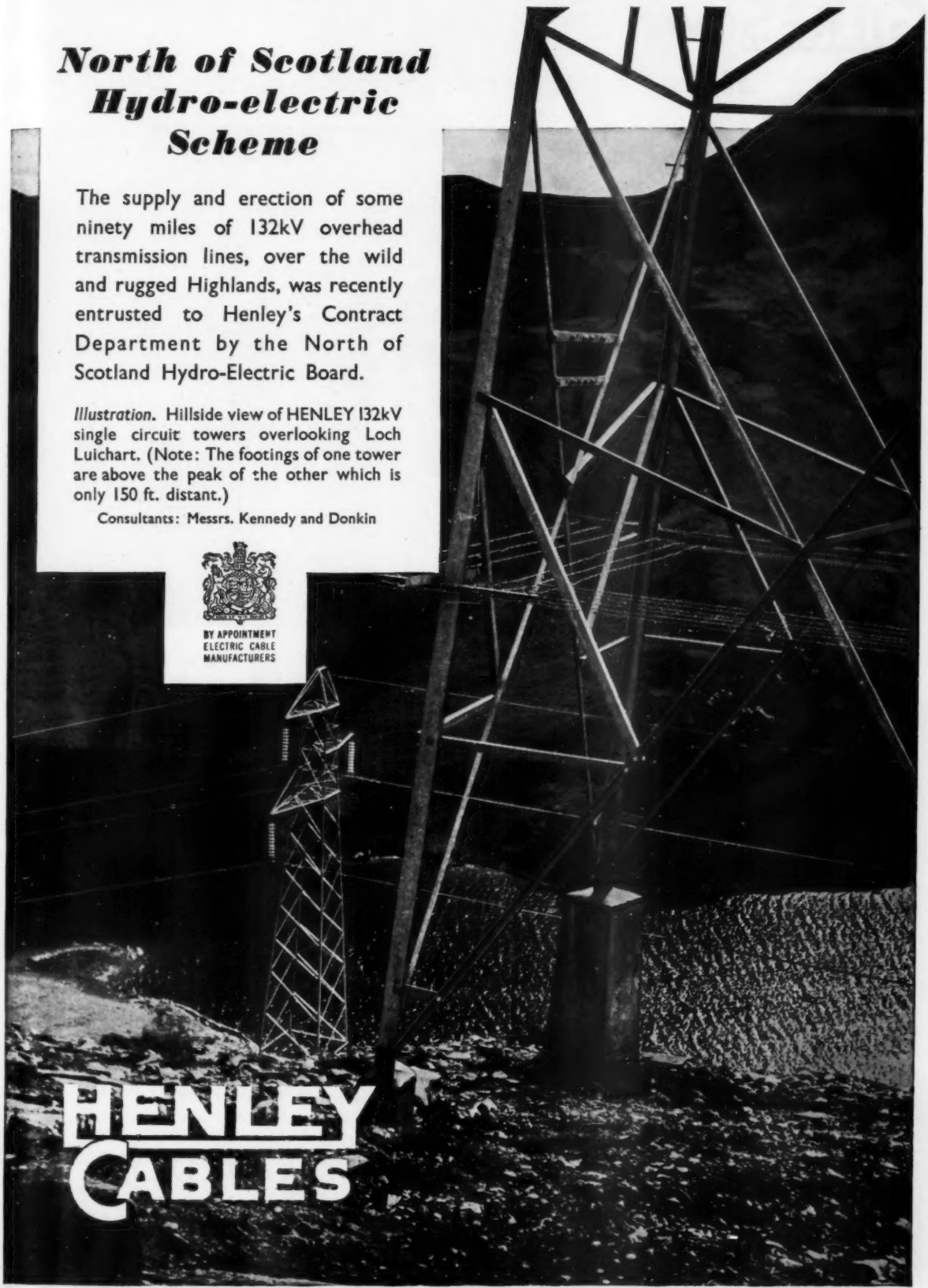
North of Scotland Hydro-electric Scheme

The supply and erection of some ninety miles of 132kV overhead transmission lines, over the wild and rugged Highlands, was recently entrusted to Henley's Contract Department by the North of Scotland Hydro-Electric Board.

Illustration. Hillside view of HENLEY 132kV single circuit towers overlooking Loch Luichart. (Note: The footings of one tower are above the peak of the other which is only 150 ft. distant.)

Consultants: Messrs. Kennedy and Donkin

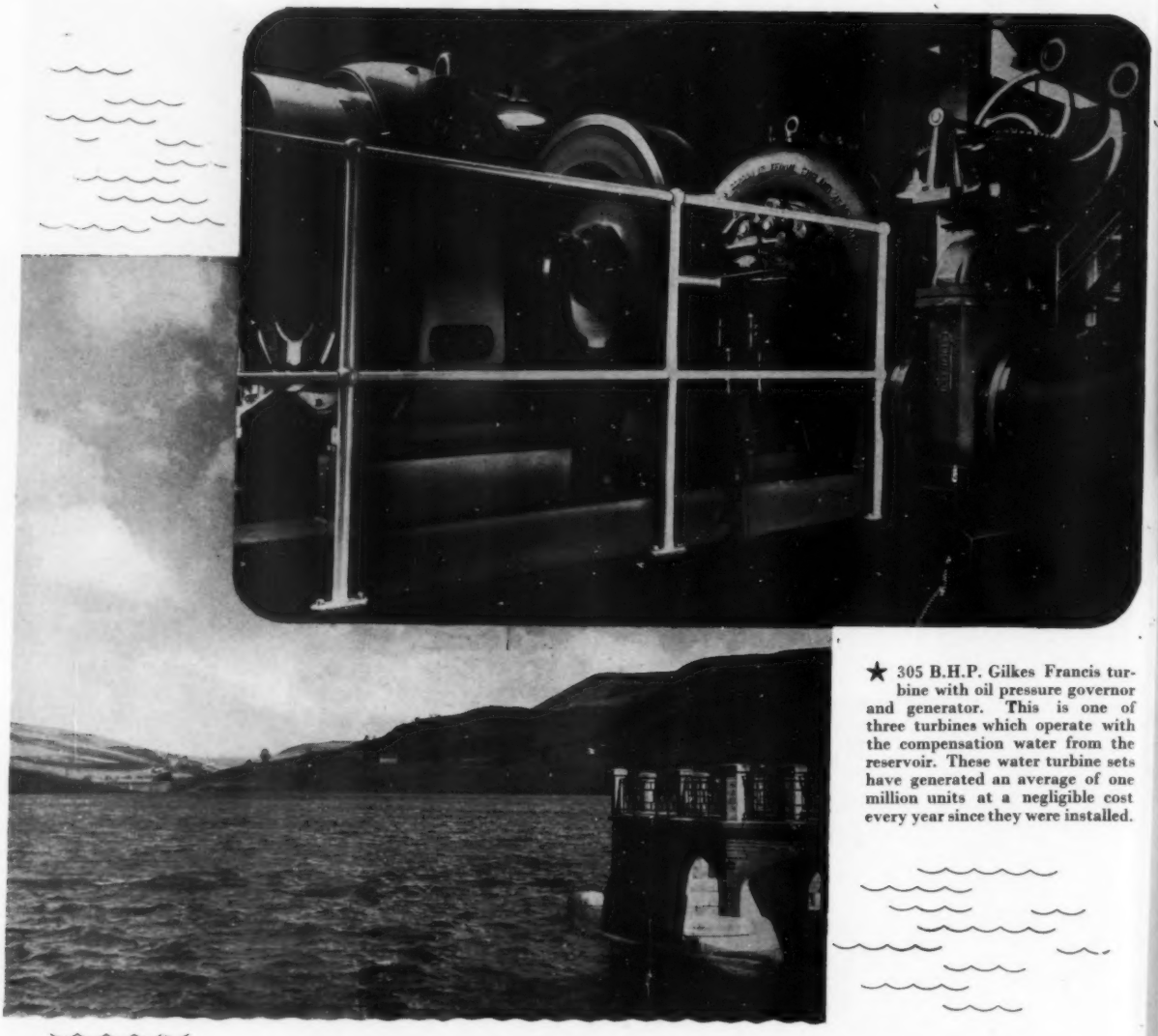
BY APPOINTMENT
ELECTRIC CABLE
MANUFACTURERS



W. T. HENLEY'S TELEGRAPH WORKS CO. LTD., 51-53 HATTON GARDEN, LONDON, E.C.1

GILKES WATER TURBINES

at the Ladybower Reservoir, Ashopton, Derbyshire



★ 305 B.H.P. Gilkes Francis turbine with oil pressure governor and generator. This is one of three turbines which operate with the compensation water from the reservoir. These water turbine sets have generated an average of one million units at a negligible cost every year since they were installed.

At the Ladybower Reservoir, one of the largest stretches of artificial water, the Derwent Valley Water Board has installed three Gilkes Water Turbines totalling 660 B.H.P.

Write for GILKES handbook: "On the Development of Water Power"

GILBERT GILKES & GORDON LTD.

KENDAL 'Phone: Kendal 28 ENGLAND

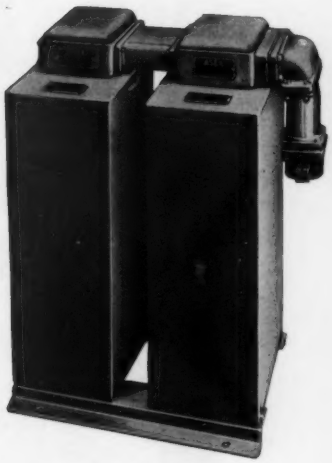
WATER TURBINE AND PUMP MANUFACTURERS

London Office: CRAVEN. HOUSE. KINGSWAY. LONDON W.C.2 *'Phone: Holborn 3232*

G.29

Three - phase capacitor battery, 1800 kVAr, 11 kV, 50 p/s, installed in a municipal power plant.

★ **Capacitors in all sizes for 230, 400 and 500/550 V can be supplied from stock at present.**



Three-phase capacitor battery, 36 kVAr, 400 V, or 24 kVAr, 230 V, 50 p/s, with cable boxes.

Are you penalized for reactive power consumption?

Is your electrical equipment overloaded?

There is an unabating increase in the demand for electric power and to-day many power supply systems are being worked to the point of failure. Asea capacitors furnish an expedient ★ and inexpensive means of improving your power situation.

ASEA Capacitors

reduce all transmission losses

improve voltage conditions in the supply mains

permit higher active loading of generators, cables and transformers

enable the power producers to supply more kilowatts and entail lower costs for energy consumed

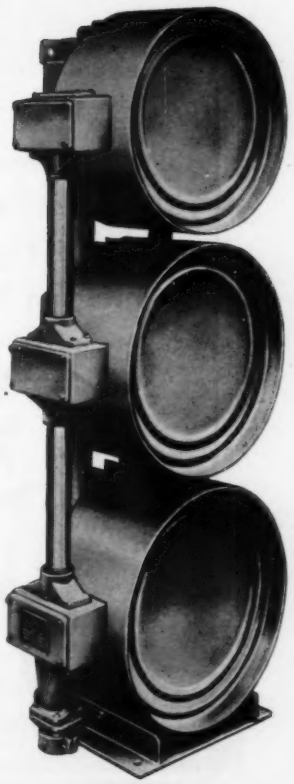
obviate penalties for excessive consumption of reactive power and energy

pay for themselves in a very short time merely by the reduction in penalties for reactive power

The capacitors are designed as standard units which can be built up into batteries of requisite size. Batteries may be enlarged by adding units, or the rating altered by transferring units from one battery to another, according to prevailing supply conditions.

Consult Asea for expert advice on your power problem.

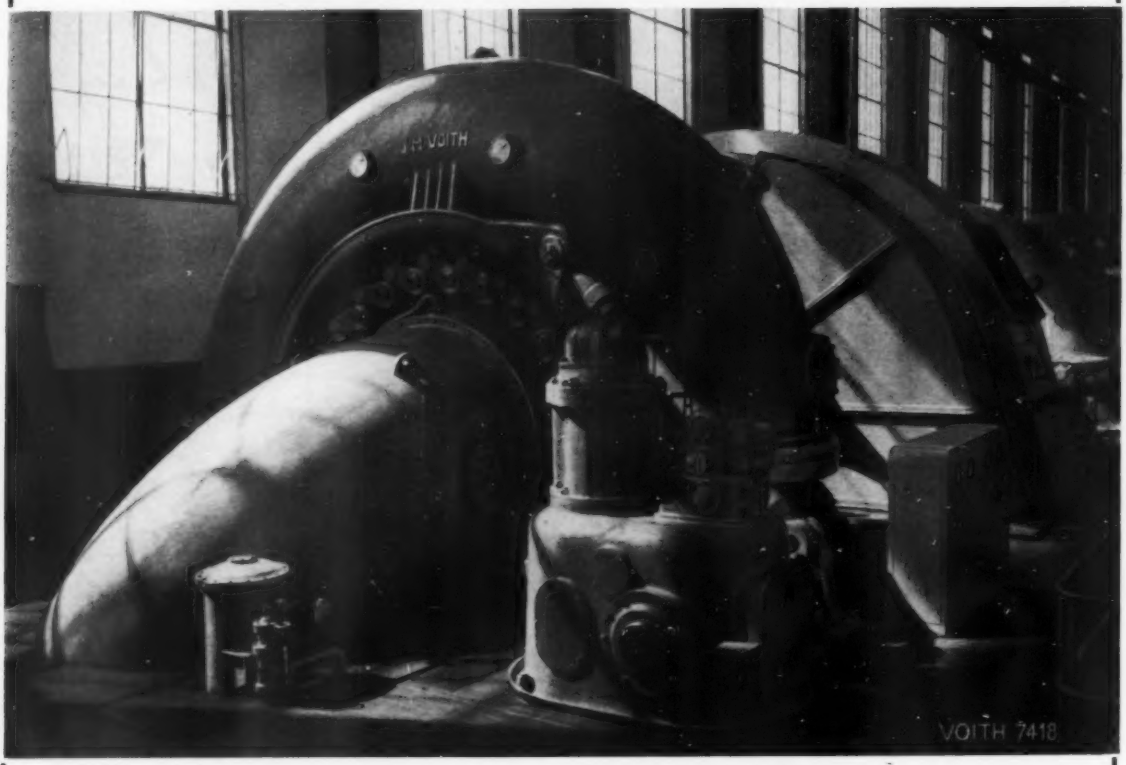
Västerås ASEA **Sweden**



Three-phase capacitor battery, 87 kVAr, 400 V, 50 p/s, mounted in frame for fixing to wall or floor.

Voith-Hydraulic Turbines and Storage Pumps

for Water Power Plants



Machine set of pump storage plant Waldshut of the Schluchseewerk A.G., turbine 60,000 H.P., storage pump 23,400 H.P.

Since **1946** we have supplied or have in manufacture:

33 Impulse Turbines above 500 H.P. for a total output of approx. 491,000 H.P.

66 Francis Turbines above 500 H.P. for a total output of approx. 757,000 H.P.

105 Kaplan Turbines for a total output of approximately 569,000 H.P. or a total of 204 turbines for a total output of approximately 1,820,000 H.P.

Our long and wide experience gained from building more than 15,000 turbines and our continuous scientific research work carried out in our test stations enable us to supply hydraulic equipment designed for maximum performance and never failing service.

J. M. Voith G.m.b.H. Engineering Works

Heidenheim (Brenz), Germany

The safe link

We specialise in manufacturing Power Transformers for Generation. Transmission and Distribution. All YORKSHIRE Transformers are designed, constructed and tested to the corresponding British Standard Specification.

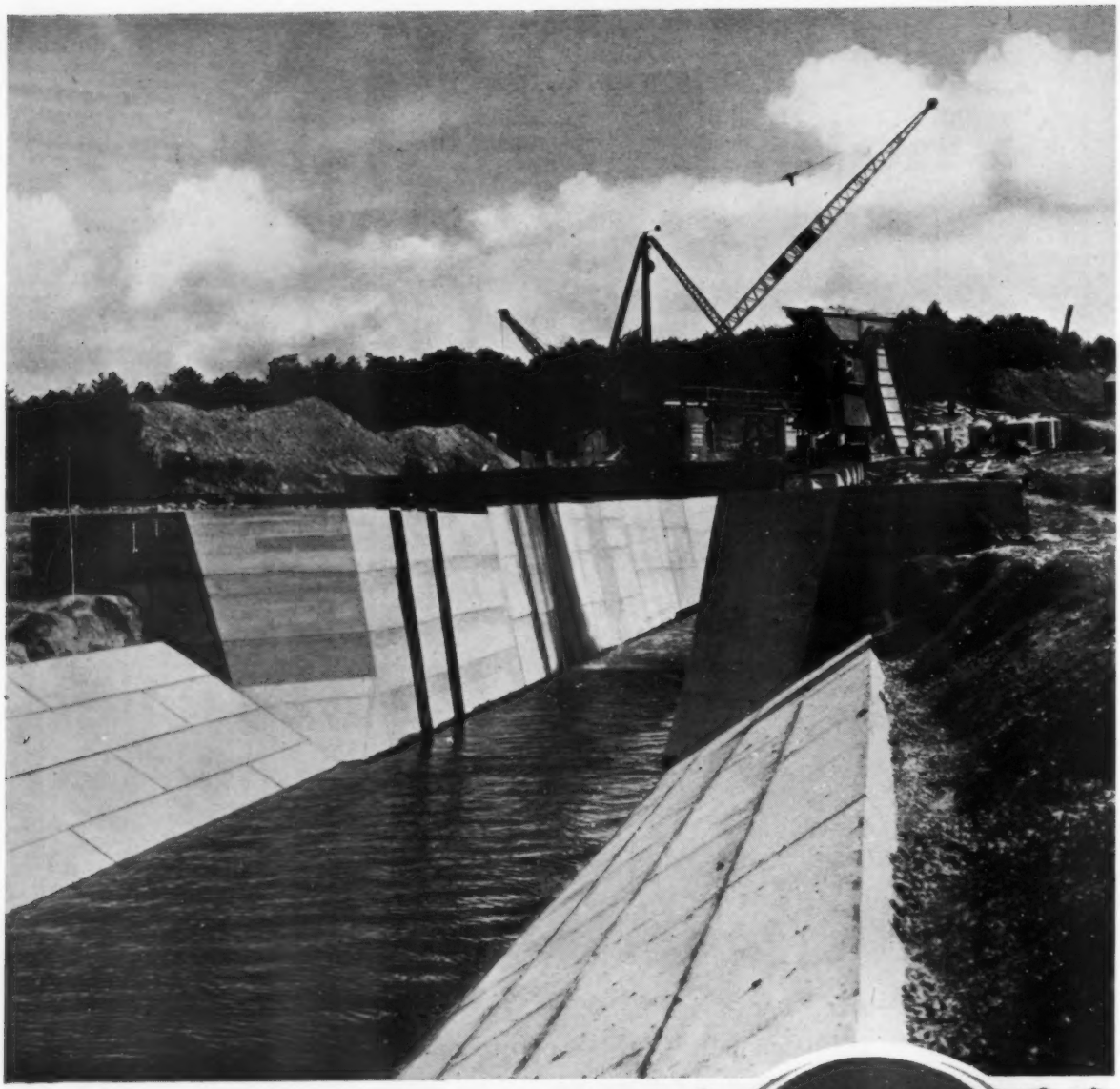
We make Transformers to suit all requirements up to 45,000 k.V.A. - 132,000 volts.

YORKSHIRE TRANSFORMER

YET

Phone. DEWSBURY 1691/2

YORKSHIRE ELECTRIC TRANSFORMER Co LTD DEWSBURY · ENGLAND



Work on the diversion tunnel and channel at the Weir Wood Reservoir Contract, which is one of the water conservation schemes being carried out by the Company

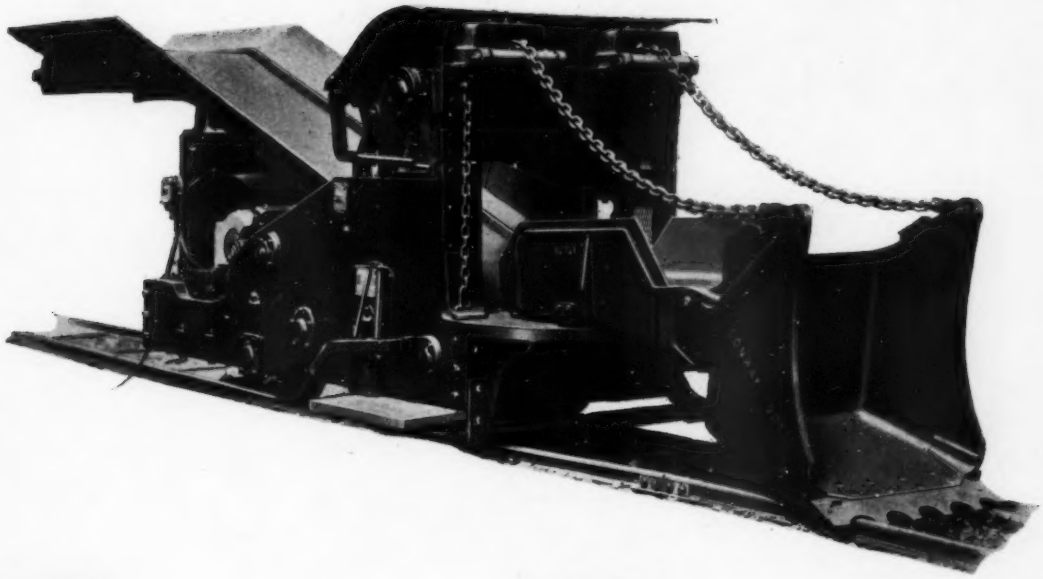
Consulting Engineers: Herbert Lapworth Partners

Richard
COSTAIN
Limited

LONDON S.W.1. VICTORIA 6624

Building & Civil Engineering Contractors

Tunnel Test It!



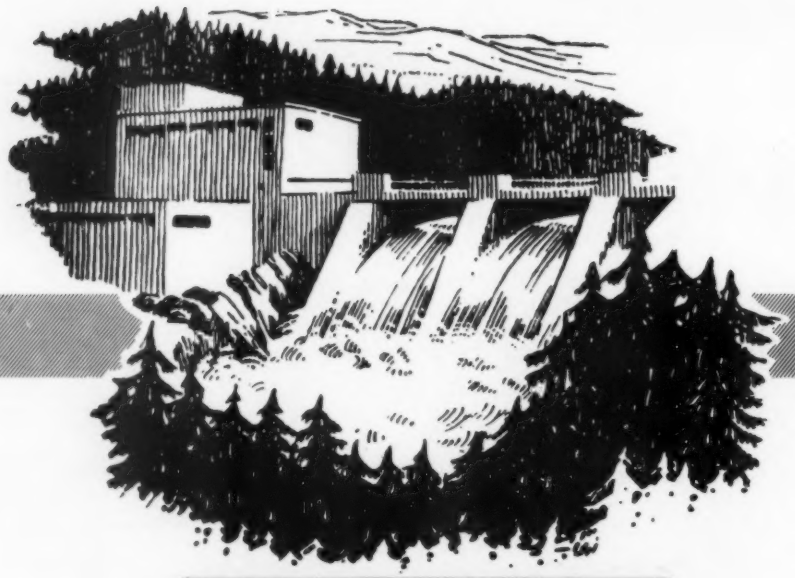
Budget Test It!

Test Conway's Fast loading cycle
Test Conway's Big loading capacity
Test Conway's low cost 'mucking out'

Whichever way you test the Conway Loader, you will be convinced that it brings much needed economy to tunnelling. Watch it in the "heading." Four loading movements: tramming, rooting, swinging (55° right or left), hoisting, all powered from one motor, by one man, in combination or independently. This singly controlled loading cycle gives biggest loading capacity and clears the "heading" without hand shovelling. Time it. A Conway loaded out 38 yards of drift in fifteen shifts at a colliery in South Wales. Working in partnership with the Conway clutch-operated endless belt conveyor, maximum loading capacity is obtained and drift tubs are charged at the rate of 130 tons and upwards per hour. *Write for Brochure describing complete Conway range.*

British Conway Loaders

BRITISH CONWAY LOADERS LTD., 3 CASTLE ST., CARDIFF **Phone: CARDIFF 8512-3-4** **Grams: Powershovl, Cardiff**



NOHAB

WATER TURBINES

WATER TURBINES have been manufactured at our works for more than 100 years. One of the first turbines, constructed in 1848 for a flour mill, is still in service—a noteworthy record.

At the present day we have possibilities to build turbines with runners up to 30 feet in diameter.

Most powerful turbine delivered by us has an output of **133.000** h.p. It is installed at the Harsprånget plant in northern Sweden.

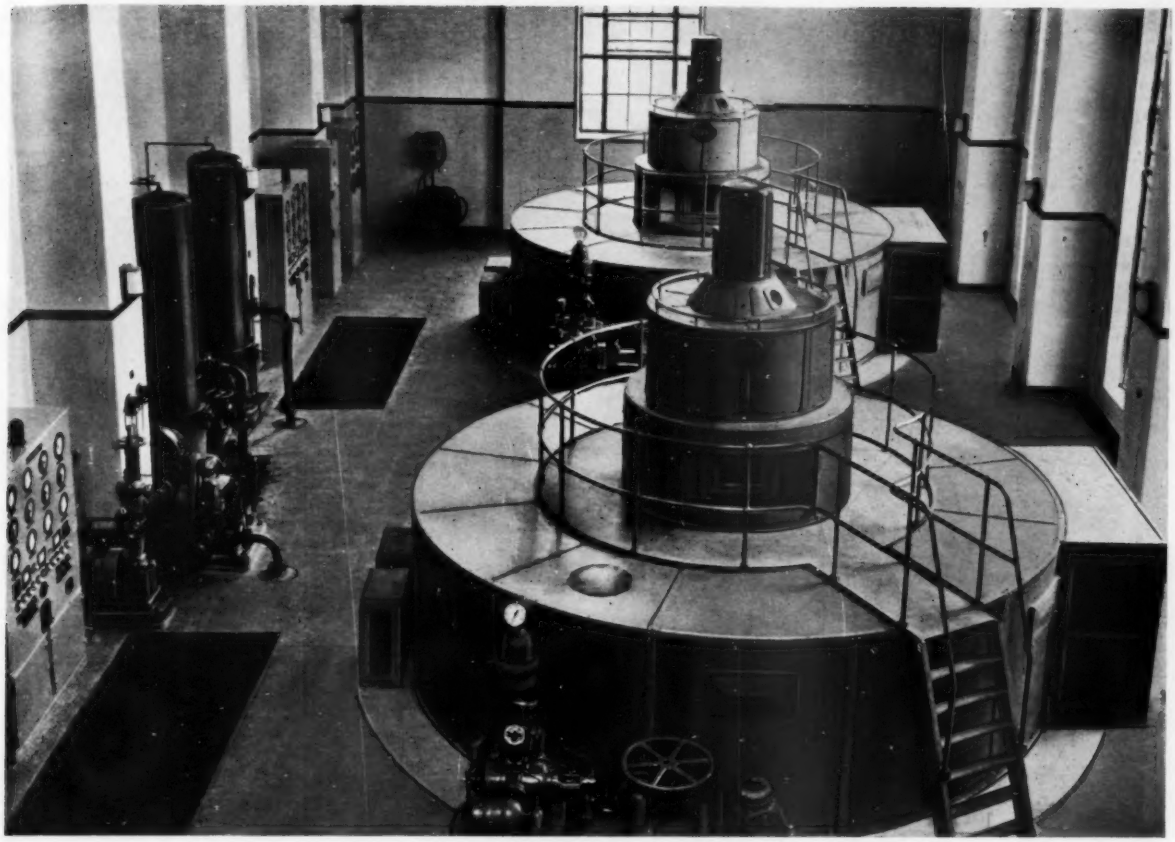
Our production includes:

GOVERNORS for automatic and semi-automatic control, also of the **ASEA-NOHAB** electro-hydraulic type.

CONTROL VALVES of various types.

GATES and other mechanical equipment for hydro-electric power.

NYDQVIST & HOLM AKTIEBOLAG
TROLLHÄTTAN
SWEDEN
Telegrams : Nohab, Trollhattan

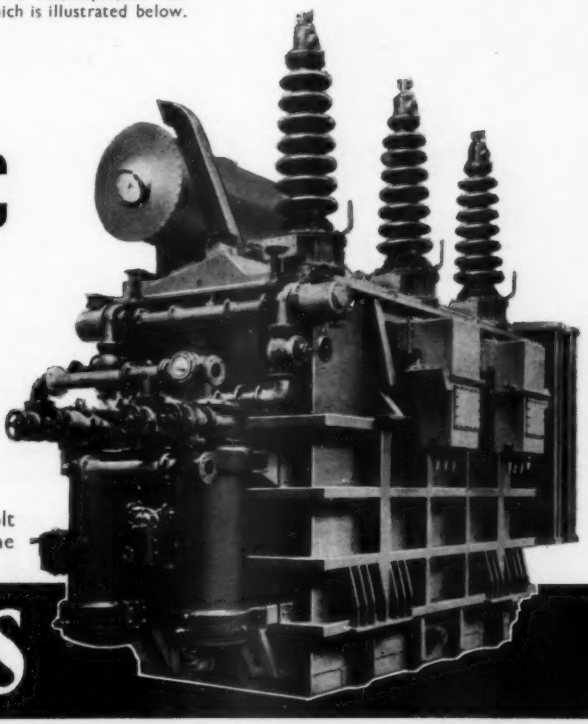


LOCH FANNICH PROJECT, North of Scotland Hydro-Electric Board. View of Grudie Bridge power station showing two 12,000 K.W. 11,000 volt, 500 r.p.m. vertical generators. The installation includes two 20,000 K.V.A. 132,000/11,000 volt water-cooled transformers, one of which is illustrated below.

PEEBLES

hydro-electric plant

Bruce Peebles build large and small generators for all types of water turbines, and transformers up to the largest sizes for hydro-electric power distribution.



20,000 kVA. 132,000/11,000 volt water-cooled transformer for the Loch Fannich scheme.

BRUCE PEEBLES

Advertisement of BRUCE PEEBLES & CO. LTD. · ENGINEERS · EDINBURGH · SCOTLAND

EUCLIDS haul ½ million cu.yds of rock to win coal!

Messrs. Henry Boot & Sons Ltd. operate a fleet of EUCLIDS at one of the toughest opencast coal sites in Britain. Here, at the Hoyland Common Site near Barnsley, nearly ½-million cubic yards of rock overburden have been excavated in the recovery of 48,500 tons of coal.

EUCLID Rear-Dump Wagons are available for Sterling.
Place your orders NOW! ***All orders executed in strict rotation***

A Complete After Sales Service is maintained by the Sole Distributors

EUCLID
THE PIONEER

BLACKWOOD HODGE

Sales:
11 BERKELEY ST., W.I.
Telephone: Mayfair 9090

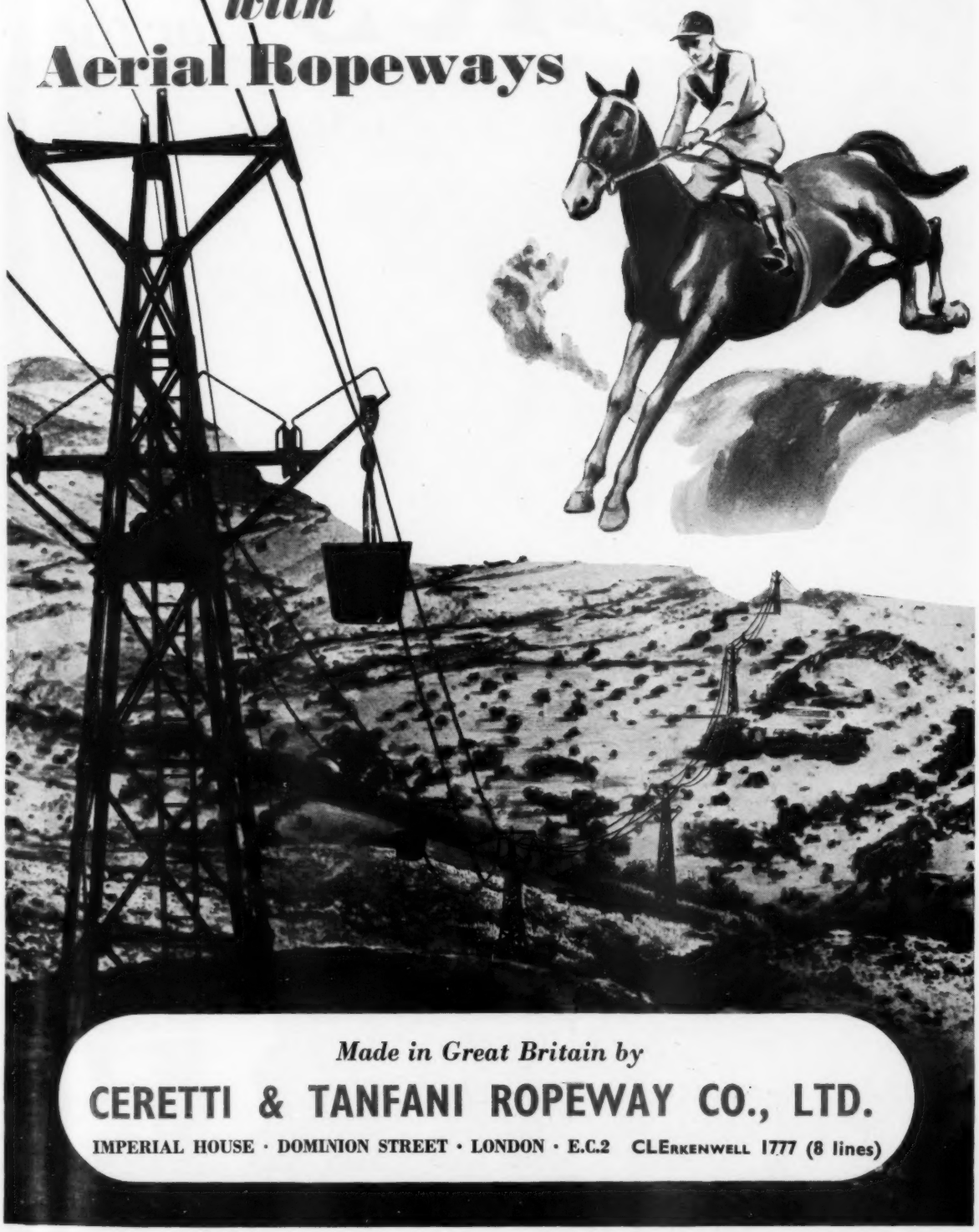
Works and Service:
HUNSBURY, NORTHAMPTON
Telephone: Northampton 5262

U.K., U.S.A., IRELAND, BELGIUM, FRANCE, PORTUGAL, SPAIN, ITALY, S. AFRICA, E. AFRICA, W. AFRICA, RHODESIAS & NYASALAND, BELGIAN CONGO, ANGOLA, MOZAMBIQUE, SUDAN, INDIA, PAKISTAN, CEYLON, BURMA, AUSTRALIA

Clear every obstacle

with

Aerial Ropeways

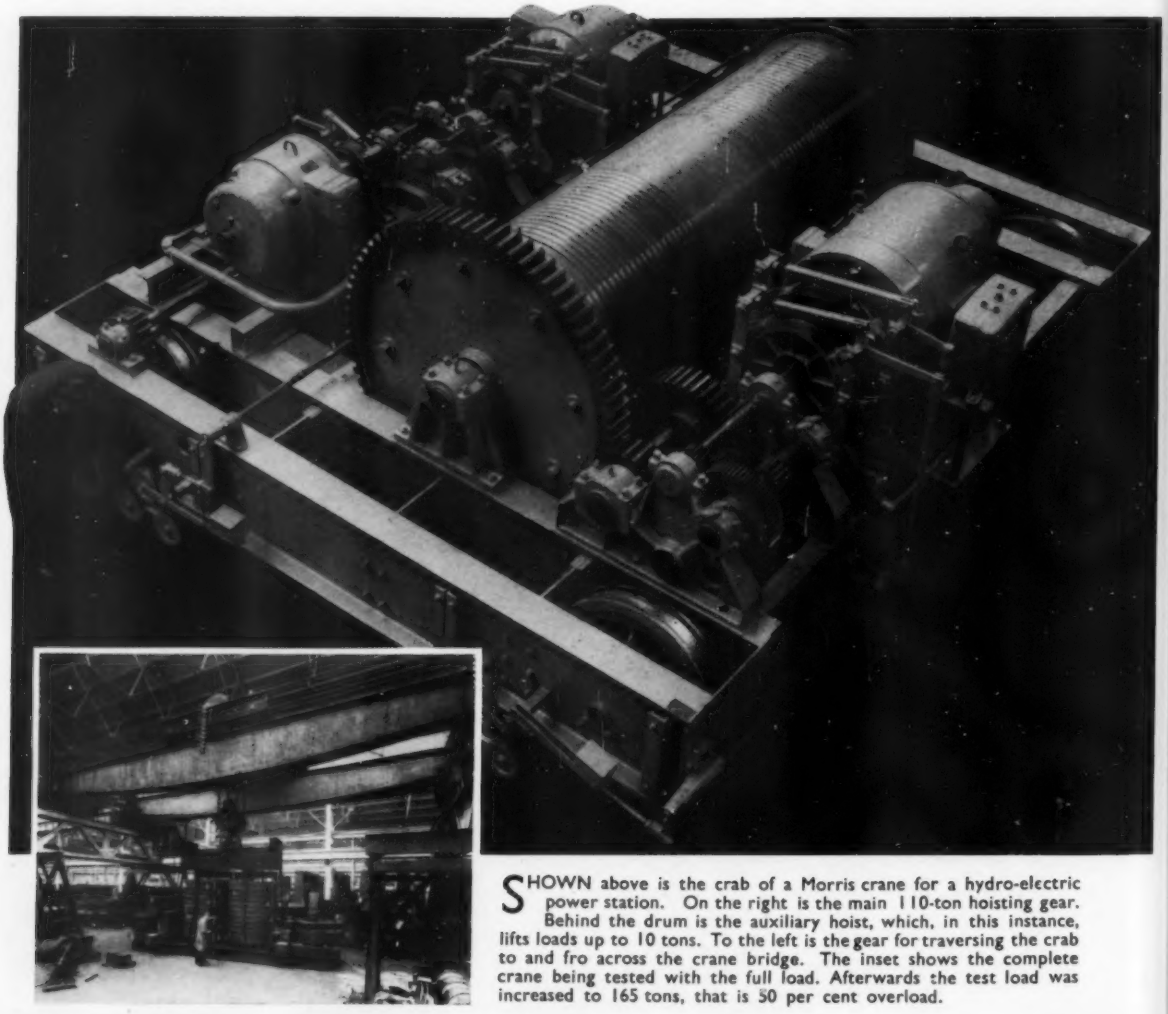


Made in Great Britain by

CERETTI & TANFANI ROPEWAY CO., LTD.

IMPERIAL HOUSE · DOMINION STREET · LONDON · E.C.2 CLERKENWELL 1777 (8 lines)

Cranes for the power station



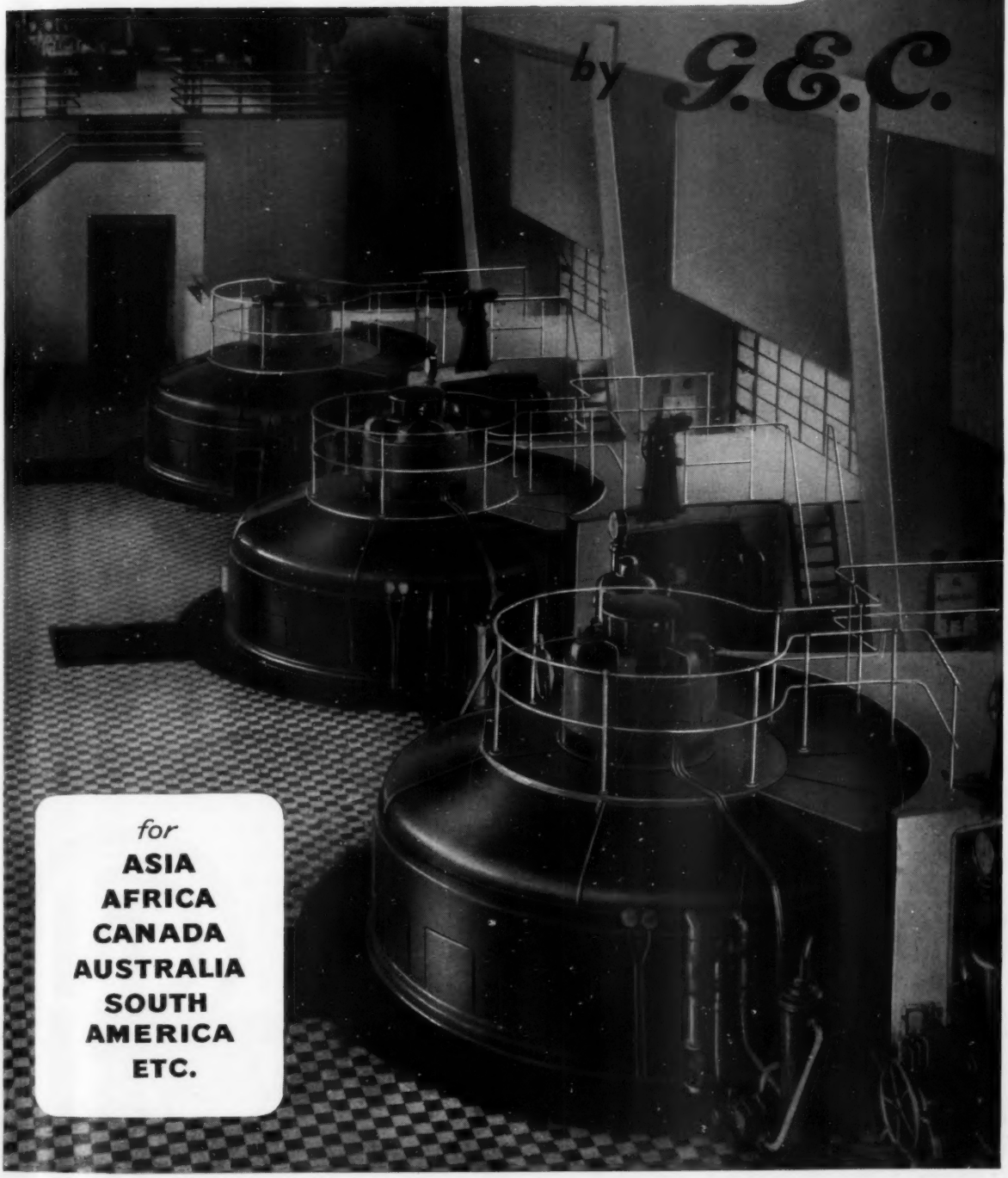
SHOWN above is the crab of a Morris crane for a hydro-electric power station. On the right is the main 110-ton hoisting gear. Behind the drum is the auxiliary hoist, which, in this instance, lifts loads up to 10 tons. To the left is the gear for traversing the crab to and fro across the crane bridge. The inset shows the complete crane being tested with the full load. Afterwards the test load was increased to 165 tons, that is 50 per cent overload.

MORRIS

HERBERT MORRIS LTD., LOUGHBOROUGH, ENGLAND

HYDRO - ELECTRIC PLANT

by G.E.C.



for
ASIA
AFRICA
CANADA
AUSTRALIA
SOUTH AMERICA
ETC.

THE GENERAL ELECTRIC CO. LTD., MAGNET HOUSE, KINGSWAY, LONDON, W.C.2

CHRISTIANI & NIELSEN

CIVIL ENGINEERS AND CONTRACTORS—ESTABLISHED 1904

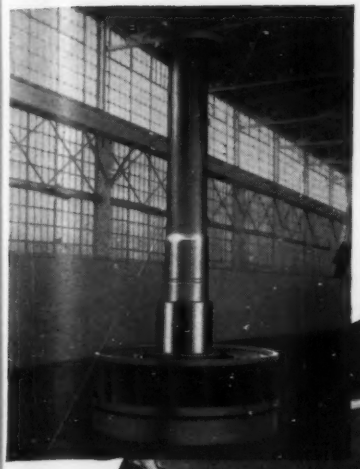
Backed by the experience gained during 48 years working in 35 countries, the Christiani & Nielsen Organisation can undertake large-scale civil engineering work of all types in any part of the world.

SPECIALITY: Marine and Hydraulic Structures.

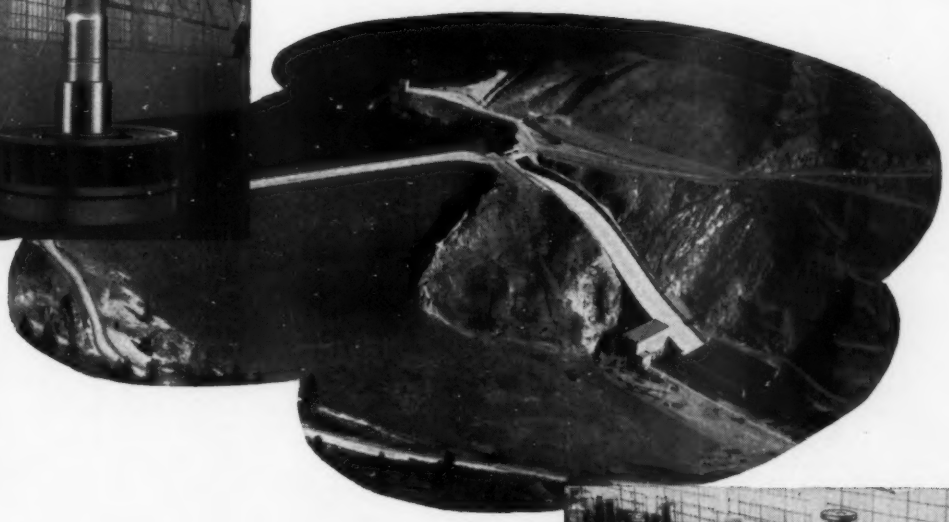
LONDON OFFICE: 54 Victoria Street, S.W.1.
Telegrams: Reconcret, London.

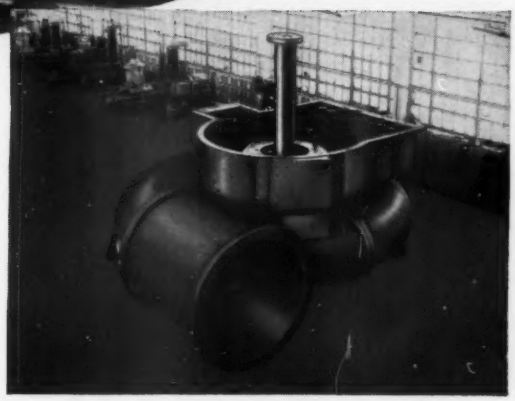
CENTRAL DESIGNING OFFICE: Vester Farimagsgade 41, Copenhagen
Telegrams: Jernbeton, Copenhagen

ALSO OFFICES IN: Aarhus - Asuncion - Bahia - Bangkok - Bogota - Buenos Aires - Cape Town Caracas - Durban - Guayaquil - Hamburg - Helsingfors - Lima - Lourenco Marques - Mexico City Montevideo - New York - Oslo - Paris - Rangoon - Rio de Janeiro - Sao Paulo - Stockholm - The Hague.



The *"Anderson Ranch"* POWER PROJECT
United States Bureau of Reclamation





hydraulic turbines by **LEFFEL**

Anderson Ranch Dam, located on the Boise River in Idaho, U. S. A., is the highest earth-fill dam in the world. Two Leffel turbines are installed in the Anderson Power Plant which provides power for the surrounding area. The turbines are of the cast steel spiral case, vertical Francis type and each is maximum rated at 28,250 HP, under 324 ft. net head, speed 277 RPM.

When you consider turbines for *your* power project (whether it is a new installation or the expansion of an existing installation) we ask you to keep in mind the services which are offered by Leffel. Our 90 years of experience, our large modern plant, our thorough workmanship — all are ready to serve you.

With a structural height of 456 feet, a base width of 2,650 feet and a crest length of 1,350 feet the Anderson Ranch Dam contains nearly 10,000,000 cubic yards of earth and rock. The reservoir behind the dam will hold 493,200 acre-feet of water.

1083

FOUNDED IN 1862

THE JAMES LEFFEL & CO.

DEPARTMENT W • SPRINGFIELD, OHIO, U. S. A.

MORE EFFICIENT HYDRAULIC POWER FOR 90 YEARS

KMW

Water Turbines for all conditions, Governors, Pipelines and Gates for hydraulic power stations.

AKTIEBOLAGET KARLSTADS MEKANISKA WERKSTAD
KARLSTAD, SWEDEN

Water, water, everywhere!

but you can work in the dry!

BLAW KNOX

WELLPOINT DEWATERING

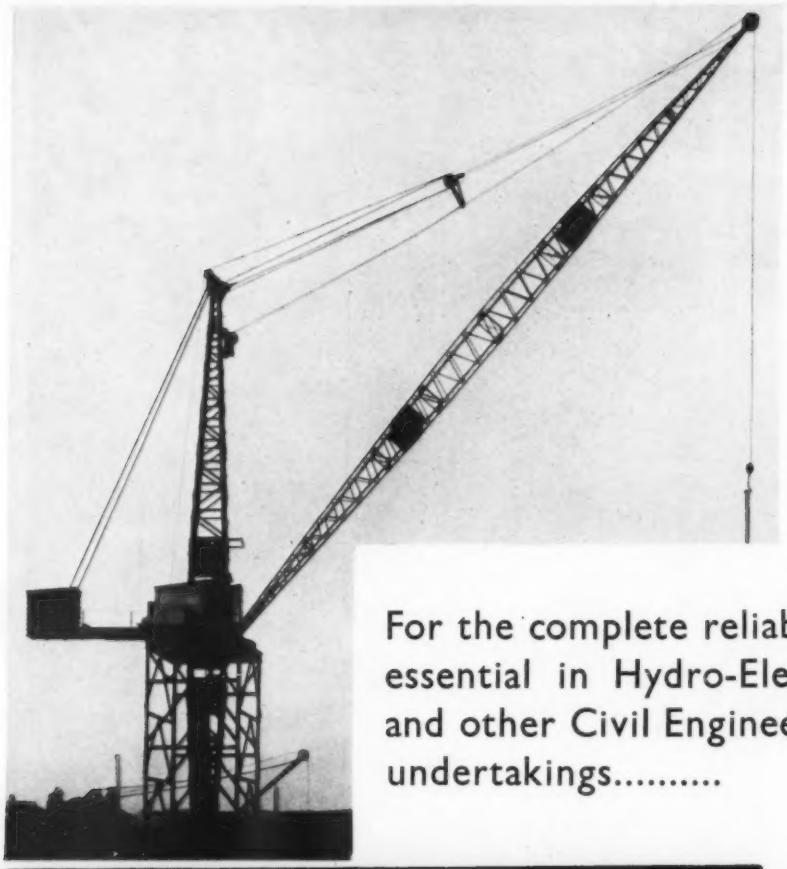
Consulting Engineers and Civil Engineering Contractors cannot be sure that the problems of foundation work in water-bearing sub-soils are being tackled with the utmost efficiency until they have at least investigated the Blaw Knox Wellpoint Dewatering System. In running sand where subsidences and "boiling" occur when timbering or sheet piling is used, and also in varied stratum, Blaw Knox Wellpoint Dewatering has proved itself to be the SURE method to make "every job a dry job", overcoming ground water difficulties which can so easily cause serious financial loss.

Catalogue No. 103 will gladly be supplied upon request.

Fast, safe and profitable progress of installation under most difficult conditions, even where ballast or heavy clay stratum is encountered, is assured by the Blaw Knox 2-valve Wellpoint (patented) which maintains full jetting pressure through the tip with no back wastage.
B.K. 61

BLAW KNOX LTD.

90/94 BROMPTON ROAD, LONDON, S.W.3 *Telephone: Kensington 5151. Telegrams: BLAWNOX, SOUTHKENS, LONDON.*



For the complete reliability essential in Hydro-Electric and other Civil Engineering undertakings.....

Butters Cranes

In over 80 years of specialised experience of crane building we have been privileged to supply cranes to many of the greatest hydro-electric and other civil engineering contracts ever undertaken, and have developed a considerable knowledge of operating conditions to be expected in most parts of the world. We are always happy to co-operate with engineers in deciding the most suitable types and sizes of cranes for any purpose and shall be pleased to submit designs and quotations on request.

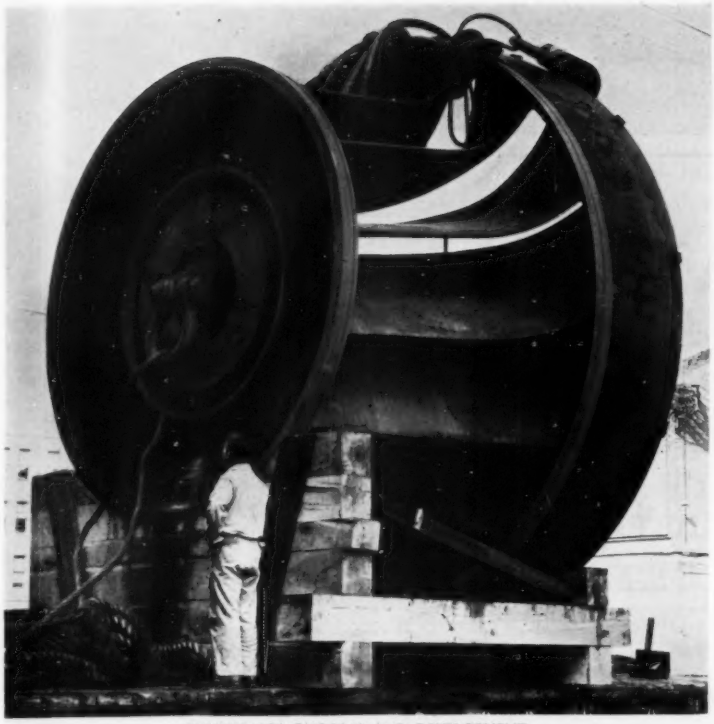
The illustrations show a monotower (top) and a derrick crane, types which have had great success in Hydro-Electric developments and which we make in a variety of sizes and powers.

Butters Bros. & CO. LTD. ENGINEERS & CRANE BUILDERS

MACLELLAN STREET
GLASGOW, S.1, SCOTLAND

Cable Address: "BUTTERS, GLASGOW"
Codes used: A.B.C. (5th Edition), A.1., LIEBERS and PRIVATE

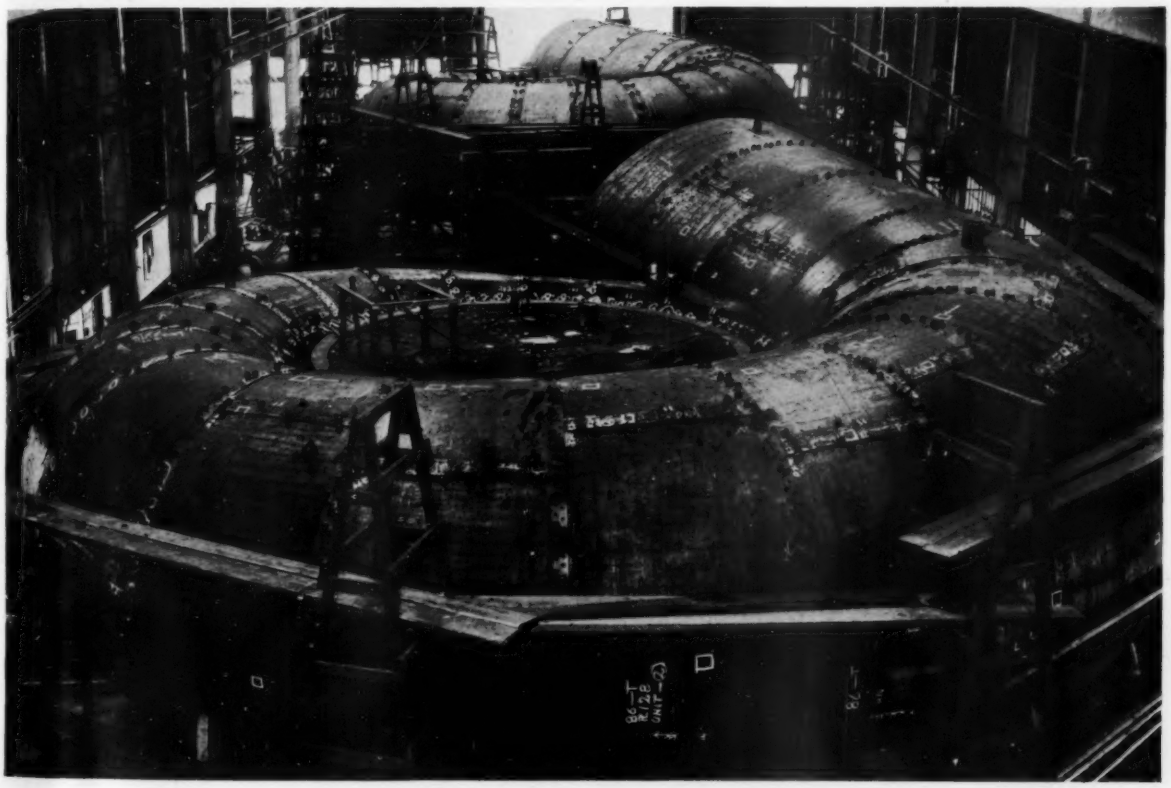
LONDON:
The Crane Works, Long Lane,
Hillingdon, Middlesex



RUNNER FOR BUGGS ISLAND DEVELOPMENT

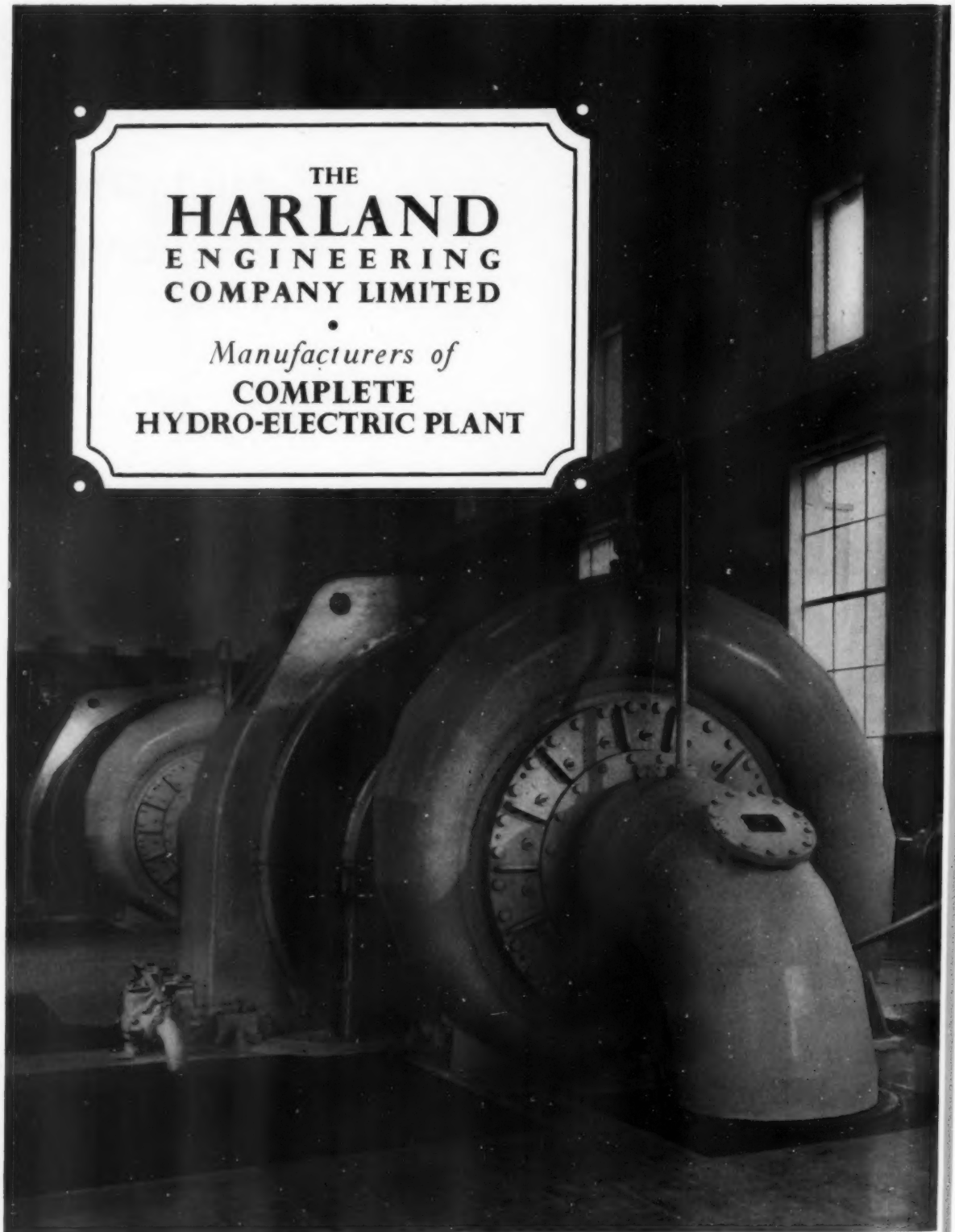
OVER EIGHT MILLION HORSEPOWER

The Newport News Shipbuilding and Dry Dock Company has received orders for the building of hydraulic turbines aggregate rated output of 8,135,000 horsepower.



ASSEMBLY OF SPIRAL CASINGS FOR C. J. STRIKE DEVELOPMENT

NEWPORT NEWS
SHIPBUILDING AND DRY DOCK COMPANY
Newport News, Virginia



Officially opened on September 26th 1951, the Loch Striven Power Station of the North of Scotland Hydro-Electric Board contains 2 - 4250 B.H.P. "Harland Morgan Smith" Francis Turbines driving 3000 K.W. "Harland" alternators—a fine example of hydraulic and electrical generating plant manufactured under one roof and erected at site by Harland specialist engineers.

THE HARLAND ENGINEERING CO. LTD., WORKS ALLOA SCOTLAND

WATER POWER

A technical journal devoted to the study of all aspects of Hydro-electric developments

Annual Subscription: 35 shillings. Single Copies 2s. 6d.

VOLUME 4. NUMBER 1.

CONTENTS FOR JANUARY, 1952

Leading Article: Energy Transportation - - - 1

Editorial Notes - - - - - - 2

Arctic Power - - - - - - - 4
By J. H. M. Sykes

Book Reviews - - - - - - - 14

A Contribution to the Study of Butterfly Valves—II - 16
By D. Gaden, Eng.

Correspondence - - - - - - - 22

Preliminary Survey for Hydro-Electric Development - 23
By E. A. Logan, M.Sc., M.I.C.E., M.I.Mech.E., M.I.E.E.

Los Peares Power Station - - - - 28

The Critical Intermittent Impact Factor in Wind-Turbine Design - - - - - - - 35
By Percy H. Thomas

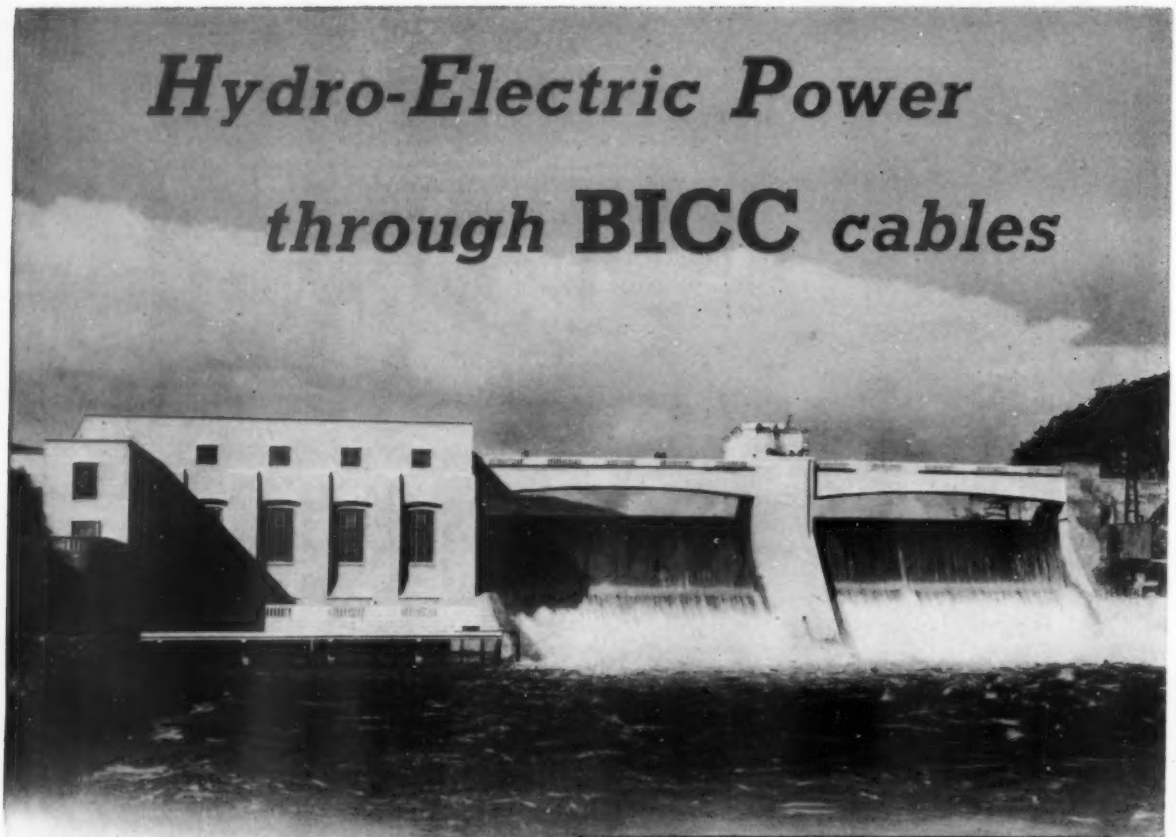
Abstracts from the World Technical Press - - 37

An Index to WATER POWER for 1951 has been prepared and is available free of charge on application to the Publishers.

Published by
Tothill Press Limited,
33 Tothill Street, Westminster, London, S.W.1.
Telegrams: Ishbuilder, Parl, London. Telephone: Whitehall 9233 (12 lines).

MANCHESTER: Century House, St. Peter's Square. Telephone: Central 3101.
BIRMINGHAM: 90 Hagley Road, Edgbaston. Telephone: Edgbaston 2466.
NEWCASTLE-ON-TYNE: 21 Mosley Street. Telephone 22239.
GLASGOW: 87 Union Street. Telephone: Central 4646.
LEEDS: 70 Albion Street. Telephone 27174.

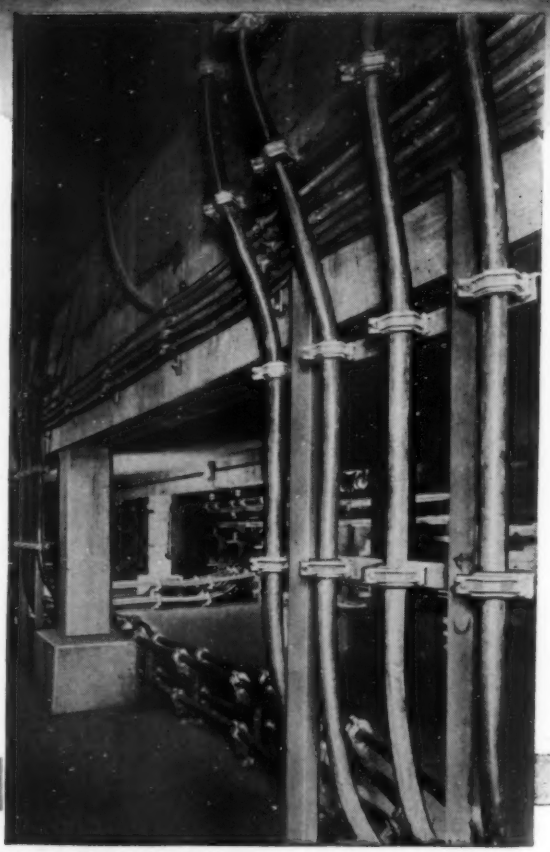
Hydro-Electric Power through **BICC** *cables*



For the two North of Scotland Hydro-Electric Board generating stations at Pitlochry and Clunie, all main power and auxiliary cables were supplied by BICC. This Company also supplied the 3-core 11kV cables and 30-core 7/.029″ auxiliary cables which link the two stations. The installation work was carried out by B.I.C. Construction Company Ltd.—a subsidiary of BICC.

The BICC Organization manufactures, supplies and installs all types of cables for hydro-electric work all over the World.

Above: General view of Pitlochry Generating Station.
Right: Run of 11kV cables from switchgear to transformers at Clunie Generating Station.



B.I. Callender's

BRITISH INSULATED CALLENDER'S CABLES · LIMITED
NORFOLK HOUSE, NORFOLK STREET, LONDON, W.C.2

Branches and Agents throughout the World

WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development

Energy Transportation

IT seems probable that in the immediate future the most difficult questions facing hydro-electric engineers will be those associated with the transportation of the energy they provide. On the whole, most of the other problems of developing electric power from falling water, if not completely solved, are at any rate approaching that position. Modern surveying methods, together with the increasing amount of statistical data available, enable reasonably accurate estimates to be made of the possible power available, and the forecasting of drought periods, which may cause grave anxiety to those operating the resulting hydro-electric schemes, is a science in which research is steadily progressing. The civil-engineering work associated with dams, tunnels, pipelines, and the like, shows, of course, continual technical progress, particularly in the direction of seeking cheaper and more rapid methods of construction, and the utilisation of materials which give long-term benefits by way of reduced maintenance. It can be said that any required civil-engineering structure can now be built.

The turbine engineers encroach gradually on the domains of higher heads for Francis machines, and low heads for variable-pitch Kaplan turbines; but they, too, with the aid of intensive model tests in various hydraulic laboratories throughout the world, can claim to be within sight of the solution of most of their major problems. The electrical engineer concerned with the generation of the energy can design alternators suitable for sizes up to 150,000 kW, and possibly larger, and he has developed techniques whereby transportation limitations no longer hamper his ability to construct the very largest units on remote sites if required.

Thus it can be fairly said that wherever water-power resources exist in whatever form (with due regard to economic feasibility) then engineers can design and construct the necessary works; but there remains the question of transporting the energy. A high proportion of available hydro-electric resources in the neighbourhood of heavily industrialised areas has by now been developed, or plans have been formulated for further projects in the near future. It is necessary to seek further afield for new sources of power, and having found them and designed methods of utilising them, of transmitting the energy to where it is needed.

The limitations of normal three-phase 50 cycle alternating current schemes are known. Higher voltages —the first obvious step—can be contemplated with equanimity, at any rate as far as 400 kV: but the great difficulty lies in stable operation. The reactance of long lines leads to instability at times of transient disturbance, and moreover it seriously limits power flow, and to combat this trouble expensive and complicated apparatus for phase-angle correction has to be installed.

For crossing the sea there is a severe distance limitation with normal a.c. transmission. Beyond about 25 to 30 miles, the charging current of an a.c. cable becomes impossibly high. A 50 cycle cable, operating at 132 kV, requires 2,000 kVA per circuit per mile charging current, and if the voltage is 220 kV —a figure perfectly practicable for modern cables— the enormous figure of 5,000 kVA per circuit per mile will be required.

The solution to the cable problem has again been found in Sweden by the utilisation of high-voltage direct current for the 62½ miles link from the mainland to the Island of Gotland. This is a particularly interesting case to hydro-electric engineers, since the prime purpose of its inception is to make hydro-electric power available on the island, where none exists. Much controversy in engineering circles still centres on the use of high-voltage direct current for lengthy overhead transmission schemes. The Swedish experiments, even if not specifically associated with overhead-line conditions, will prove an extremely valuable pointer as to the possibilities of this new form of energy transmission.

The longest a.c. transmission line in the world— the 300 MW feeder from the hydro station in the far north of Sweden 600 miles to the south—is to operate at 380 kV. The results of the first few years of use will be awaited with interest in many quarters.

In Africa, in northern parts of Canada, in parts of South America, and in Europe itself — in the north of Sweden and Norway, Finland and the U.S.S.R.—there exist vast reserves of energy which can, from the technical point of view of the hydro-electric engineer, be transformed into electricity; the transmission specialist has yet to prove that he can bring them over the thousands of miles, over forest, mountains, desert, and sea, which separate them from the places where the energy is needed.

Lake Nyasa Survey

A FULL-SCALE investigation into the possibility of utilising the waters of Lake Nyasa has been undertaken by Sir William Halcrow and Partners. During the past two years, the problems of lake stabilisation, hydro-electric power development, control of the Lower Shire and power irrigation have been studied and these projects appear to be practicable. The complete survey will be a major operation over the next two years and may cost up to £300,000. A provisional site for a barrage to control the lake level has been selected and preliminary plans for the investigation have already been drawn up. Plans have also been made for the creation of a Hydrological Section to begin the systematic collection of water data with a view to its fuller use in future years.

Drakensberg Conservation

MR. J. G. STRYDOM, South African Minister of Lands, said recently that the country on the eastern side of the Drakensberg and the Eastern Transvaal would, in future, be the scene of tremendous industrial developments. Because of the great possibilities for the conservation of water from the Drakensberg, he thought there was no other part of the country better suited for development. It would eventually be necessary to conserve every drop of water that fell on the mountain ranges, but this would take generations to accomplish.

The Damodar Valley Project

THE Damodar Valley Project is one of the biggest multi-purpose projects in India. It was born of the 1943 flood, and its primary aim is to prevent the recurrence of such disasters. The scheme consists of eight storage dams with hydro-electric stations and two auxiliary plants with a total installed capacity of 240,000 kW, an additional 200,000 kW steam power station to even out seasonal variations of hydro-electricity, a power-transmission grid which will initially include 475 miles of 132 kV, 30 miles of 66 kV and 100 miles of 33 kV lines, an irrigation barrage with associated canals and distributing system measuring 1,553 miles, and a 90-mile long irrigation-cum-navigation canal.

Together, the dams will ensure the valley against floods up to 1,000,000 cusecs as against the highest recorded flood of 650,000 cusecs. The barrage and irrigation project will provide year-round irrigation for approximately 1,000,000 acres which, at a conservative estimate, is expected to produce 9,700,000 maunds (28 lb.) of extra food annually. The direct benefits of the scheme, translated into terms of current prices, will add Rs. 25 crores at the very least to India's yearly national income. Its indirect benefits are even greater, as the cheap power it will provide in large quantities must promote rapid industrial expanson which alone can offer a radical cure for India's chronic ills.

The project has been under active implementation since July 1948, when the Damodar Valley Corporation was set up by the Central Act. The first phase of the project, covering about five years, now comprises the building of four dams at Tilaiya, Konar, Maithon and Panchet Hill, the barrage and irrigation system, and the Bokaro thermal power plant with the associated transmission lines and substations. Of these, the Panchet Dam and the irrigation works are still in the preparatory stage; but everywhere else the actual construction has progressed considerably.

Ireland's Hydro-Electric Programme

THE coming into operation of a new generating station on the River Erne, at Ballyshannon, Co. Donegal, has boosted the Irish Electricity Supply Board's generating capacity by 22,500 kW—nearly ten per cent. of last year's total output. The Erne hydro-electric scheme, costing £750,000, is being carried out under an agreement between the Northern Ireland Ministry of Finance and the Board which operates in the Republic.

Borrowing Powers for Scotland

IN the House of Commons on Thursday, November 15th, Mr. James Stuart, the Secretary of State for Scotland, introduced the Hydro-Electric Development (Scotland) Bill, which was formally read a first time.

The purpose of the Bill is to raise the limit on the amount of borrowed money which the North of Scotland Hydro-Electric Board may have outstanding at any time (apart from money borrowed to meet the compensation paid to undertakers whose undertakings vested in the Board under the Electricity Act, 1947) from one hundred million pounds to two hundred million pounds. Loans raised by the Board may be guaranteed by the Treasury under section 14 of the Hydro-Electric Development (Scotland) Act, 1943, as amended by subsection (7) of section 47 of the Electricity Act, 1947. The potential charge which may arise on the Consolidated Fund by the giving of guarantees is increased by the proposed extension of the Board's borrowing powers. Any such charge will be repayable by the Board. No charge has so far fallen on the Consolidated Fund.

Snowy River Engineers Train in U.S.A.

TWELVE Australian engineers a year will be trained at Denver, Colorado, for the Australian Snowy River hydro-electric project under an agreement signed in Washington. The agreement also provides for the designing of part of the equipment by the U.S. Bureau of Reclamation. Mr. James Webb, Acting Secretary of State, who signed the agreement for the United States, said: "I realise what an important project this is for Australia and I know the Australian engineers will get excellent training at Denver, as I have first-hand knowledge of the Bureau's installations there." Mr. Percy Spender, the Australian Ambassador, signing for his country, said: "This project will have far-reaching consequences for Australia in the provision of additional power facili-

ties and 100,000 acres of irrigation land." The first four engineers to be trained are Mr. Allen McConnel and Mr. John Hunter, of Sydney, and Mr. William Wilkin and Mr. James Williamson, of Victoria.

Orange River Development

A CONFERENCE to discuss the development of the Orange river began at Colesberg on November 20 under the chairmanship of the Minister of Lands and Irrigation, Mr. J. G. Strdom. The Caledon and Orange River Regional Development Association proposes that the largest dam in the world should be built to inundate part of Basutoland and provide as much electric power as all the Escom stations supplying the Rand. The Association wants a dam 550 ft. high at Zastron as a means of developing industry all along the Orange river.

The Eastern Province insists instead that 1½ million acre feet of water must be diverted from the Orange yearly to irrigate 250,000 morgen in the fertile valleys of the Fish, Bushmans and Sundays rivers. Another claim by the lower Orange river valley is that the whole flow of the Orange should irrigate 400,000 morgen on both sides of the river from the Buchuberg dam well into South-West Africa.

New Swedish Power Plants

THREE new power stations are to be built in North Sweden during the next five years, according to a scheme recently presented by the State Power Board. The largest of these stations, the Lasele plant on the Angerman River, will have a maximum capacity of 110,000 kW and an annual output of 600,000,000 kWh. The Näverede station on the Indal River is planned for a capacity of 63,000 kW and an output of 330,000,000 kWh, while the corresponding data for the Stuguforsen station, on the same river, are 35,000 kW and 180,000,000 kWh. The total cost of the new plants is estimated at £11,725,000.

Tasan power plant, now under construction in West Sweden for the City of Karlstad and the big steel and timber group Uddeholms AB, will have a head of 880 ft., the highest on record in Sweden. The new power station, which will cost Kr. 32,000,000 (£2,207,000) is designed for an annual production capacity of 75,000,000 kWh. The building of the plant has involved the construction of an artificial lake seven and a half miles in length and half a mile wide.

United Nations Hydro Study

AT a recent meeting in Geneva of the United Nations Economic Commission for Europe, electric power experts from eleven countries initiated two major international studies, the first to deal with rural electrification and the second to try and determine the reasons for the considerable difference in costs of construction of hydro-electric plants among European countries, with the hope of reducing costs as such construction takes place. The expert group agreed that conclusions of this study of cost differences would be useful as a point of comparison of methods in developing new sources of hydro-electric power in Europe. A draft study prepared by the Secretariat will serve as a basis for the group's work. Another expert group is seeking to establish a statistical questionnaire designed to keep the ECE Electric Power Committee informed as to power plants and transmission lines recently put into service, currently under construction or planned in European countries.

Marguerite River Project

A NEW company under the name of Gulf Power Company, Clarke City, Quebec, has been constituted to proceed with the Marguerite River development, brief details of which were given in our May 1951 issue. This company is financing the construction and will operate the plant when completed. The project is being prepared by Stadler, Hurter & Company, consulting engineers, Montreal. Construction has now started and the plant is scheduled to be in operation between the autumn of 1953 and the spring of 1954.

Power from Water Supply

FIFE Water Supplies Committee are planning the installation of turbine plant at their Glendevon reservoir to harness the passage of water from the upper to the lower reservoir. The capital cost of the scheme is estimated at £20,000 and an annual income in the region of £2,000 is visualised. The County Engineer, Mr. C. Huddleston, who advanced the proposals, said it would be possible to discharge through one or more turbines of about 800 h.p. The average annual output derived from this source is estimated at 1½ million units and informal discussions have taken place with the North of Scotland Hydro-Electric Board whereby the Board will purchase power delivered to their line.

This somewhat unusual application of reservoir power opens up possibilities for further exploitation, although legal limitations as to generation authority would undoubtedly require to be discussed with the body responsible. There does seem scope, however, for the use of any such source of water power, the more so if two ends can be served by designing reservoir outfalls to facilitate generation.

Artificial Rain

REFERENCE is made in the annual report of the Overseas Food Corporation to artificial rain precipitation in Kongwa. Behind it is the story of an interesting series of experiments involving the floating up into the clouds of balloons containing silver iodide and exploded by time fuses. Success for the experiments is claimed by experts on the spot, and there seems little doubt that rain was duly made to fall by these methods. But to stop it, when enough had fallen to suit the crops, proved beyond the powers of all. It is even said that one experiment resulted in a heavy hailstorm never before known in Tanganyika. More study is also needed to localise the rainfall.

Canadian Approval for British Plant

MANY British manufacturers, interested in the Canadian market, may be unaware of the facilities which have been established under the aegis of the British Standards Institution to facilitate approval of their equipment for export to Canada. No fewer than 220 applications for Canadian Standards Association approval were received by the British Standards Institution during the first year's operation of the scheme to speed up approval of British electrical equipment intended for the Canadian market.

Fig. 1. Falls at Harsprånget before the construction of the power station

Arctic Power

J. H. M. Sykes describes the Harsprånget scheme, situated on the Stora Lule river in the Arctic North of Sweden. An output of 1,800 million kWh per annum will ultimately be transmitted to the industrial south at 380 kV. Mention is also made of stations under construction at Ligga, Kilforsen and Lasele.

IN view of the rate of rise of electrical demand in Sweden, it has been necessary for the Swedish authorities to consider, in recent years, the harnessing of water-power supplies in areas remote from the industrial south. The majority of the available hydro-electric sources in the central and southern regions has already been utilised, and the immediate utilisation of the remainder is either contemplated or in the process of being carried out. A power station put into service in 1915 in the extreme north, at Porjus, has

now been completely developed, and it was decided to commence the construction of a series of six further power stations on the Stora Lule river, which is approximately on the level of the Arctic Circle, and flows into the Gulf of Bothnia. The topography of Sweden is such that the greater part of the demand for power is always likely to come from the southern areas, so that the utilisation of water power in the far north involves the transmission of large blocks of power over long distances.

The solution to this problem in the present instance has involved the construction of a three-phase a.c. transmission line (to be followed by at least two others) of 900 km. (approximately 600 miles) in length, operating at 380,000 V.

The first of these northern developments is the Harsprånget plant, which is situated on the river about thirty miles above the Arctic Circle, and about 5½ miles below Porjus. It will become the largest hydro-electric power plant in Sweden, and the units involved are the second largest in the world, each turbo-generator being rated at 105,000 kVA and being capable of 115,000 kW output. The only larger units at present envisaged or in service are the 125 MW sets at Grand Coulee in the U.S.A.

There are a number of other developments in the north, one of them—at Ligga—being situated on the same river as the Harsprånget plant. The Ligga station, which is 11 km. downstream from Harsprånget, will first comprise two 70 MW vertical Kaplan turbines, operating under a head of 40 m. and will be in commission in 1954.

On the Ångerman river, some 400 km. south of Harsprånget, there are two important projects. One is at Kilforsen, and the other at Lasele.

The Kilforsen plant will contain three units totalling 240 MW, and will provide an annual output of 1,200 million kWh. This scheme is unique in the sense that the plant, situated between two rivers, will be fed by the largest tunnel in the world. Its size is dictated not only by the need for bringing in the water to the sets, but also by the necessity of providing a means for floating timber. Seeing that this commodity is, of course, one of Sweden's greatest exports, it is obvious that no obstruction must be placed in the way of transporting the logs from the forests to the sawmills.

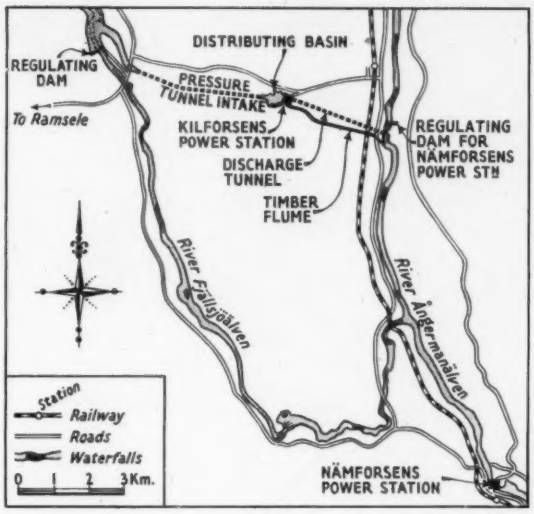


Fig. 3. Site plan of Kilforsens power station

The tunnel at Kilforsen will be 3·7 km. in length, and will have the very large cross-sectional area of 208 sq. m. (2,238·89 sq. ft.). In the top of the tunnel, which is of horseshoe shape cut in the solid rock, a telpher line "railway" will be built, on which diesel-driven cars will carry the personnel who are concerned with the manipulation of the logs. The tunnel under construction is seen in Fig. 8. It is hoped that the first and second units at Kilforsen will be in commission by 1953, and the third in 1954.

The Lasele project comprises an underground station of 110 MW, made up of two units of 55 MW each. The anticipated production is 600 M kWh per annum.

An earth-fill dam, of a length of about 300 m., will be built, with a height of 21 m. The head will be 54 m. The discharge tunnel will have a cross-

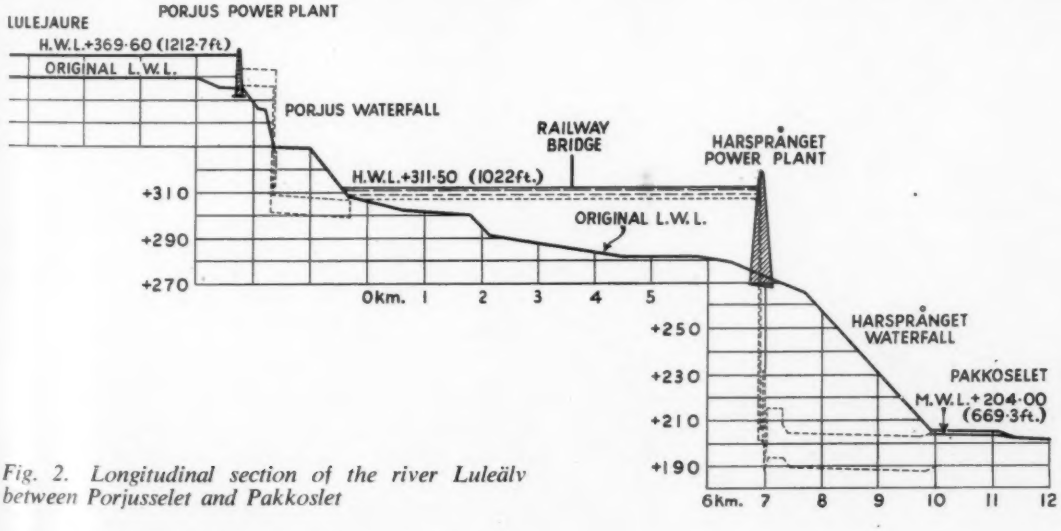


Fig. 2. Longitudinal section of the river Luleälv between Porjusselet and Pakkoslet

Fig. 4. View of Kilforsens site

section of 155 sq. m., and will serve as both tunnel and canal. Its length will be of the order of 2,600 m. The expected cost of this project is 85 million Swedish crowns, and the station is scheduled for operation in 1957.

Again to the south, two projects are planned for inception on the Indal river. The first, at Näverde, is a low-head station, with a fall of 12·5 m., and will contain two units totalling 62 MW, and producing 330 M kWh per annum. Kaplan turbines will be employed. Construction work is scheduled to start in the spring of 1952, and the station, which will cost 44 million Swedish crowns, will be in operation in 1955.

The second plant on the Indal river is to be constructed at Stogun, and here again Kaplan turbines will be employed to harness a low head of 7·2 m. The total capacity will be 35 MW, in two units. The constructional programme is approximately the same as that for Näverde, and the cost will be 38 million Swedish crowns.

Of all these schemes, that at Harsprånget is the only one which is at present in partial commission, the first unit having been placed on load on March 11, 1951. The second followed in October, and the third is expected to be on load by the early spring of 1952.

The catchment area of the Lule river, as far as Harsprånget, comprises about 10,000 sq. km. (4,000

Fig. 5. Compacting the dam with water jets

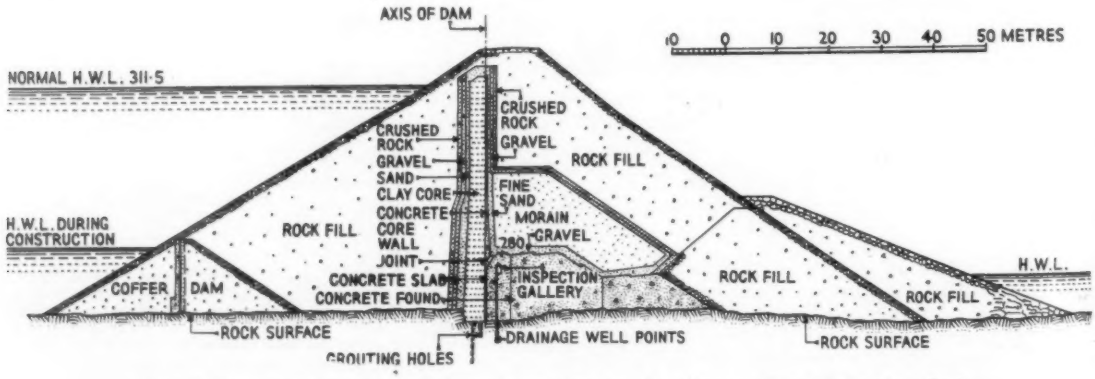


Fig. 6. Cross section of the Harsprånget dam at the deepest part of the river bed

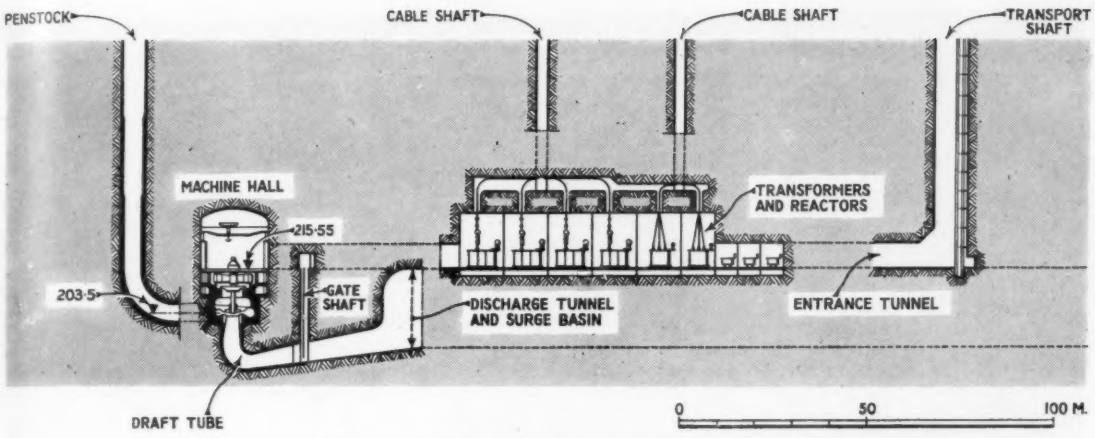


Fig. 7. Cross section through Harspránget power station

sq. miles). The mean water flow is 255 cu. m. per sec. (9,000 cusecs). The earlier dam at Porjus provides adequate means of regulating the river flow over daily or weekly periods.

The dam at Harspránget has a maximum height of 45 m. (148 ft.) up to the high-water level (1,022 ft. above sea level), and is 780 m. (2,560 ft.) in length. In addition, a subsidiary dam extends along the left bank upstream, and this is 650 m. (2,130 ft.) in length. The average gross head of the plant will be about 107 m. (351 ft.).

The dam is of the rock-fill type, and comprises a vertical concrete member as a core wall, which is only 40 to 100 cm. in thickness. The foundation is grouted into solid rock in the river bed, and a massive concrete foundation has been provided as a base for the core wall. An asphalt joint secures the vertical portion of the core wall to the foundation just below the highest point of the latter section. Fig. 6 shows the type of construction employed.

In front of the core wall is a clay core to prevent percolation, and immediately behind the wall is a layer of fine sand, backed by gravel to catch such particles from the clay core as might escape through possible cracks in the core wall. The core wall itself and the foundation slab are designed without contraction joints, the reinforcing bars passing through all constructional breaks. The concrete mixture used includes low-heat cement.

The fill materials on either side of the core wall were largely provided by the rock excavated from the machine hall and the tunnel, the total volume needed amounting to about 1½ million cu. m. (2 million cu. yards). This material was placed in position in thin layers and compacted by the use of caterpillar tractors, pulling special teethed rollers; washing was also employed to assist settlement. The clay was also compacted by tractors, and on many occasions a temporary roof had to be erected when inclement weather made it otherwise impossible to proceed. In times of extreme rainfall, however, a stiffer mixture of clay and gravel was used. The upstream face of the core wall was coated with asphalt to reduce friction and facilitate settlement.

Wells have been placed in many parts of the dam, so that measuring instruments can be inserted to check possible settlements and deflections.

On the right hand of the dam a spillway is provided, consisting of three openings separated by concrete piers and shut off by means of taintor gates. The spillway will be capable of discharging 2,200 cu. m. per sec. (77,700 cusecs); two of the gates are operated by electric hoists, but in case of current failure counterweights are fitted to open a gate rapidly in case of sudden cessation of the water flow to the

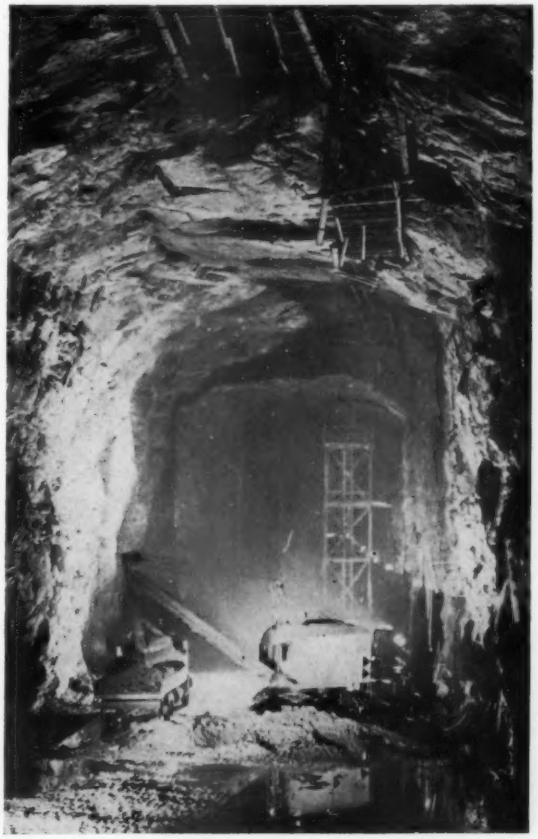


Fig. 8. The discharge tunnel at Harspránget

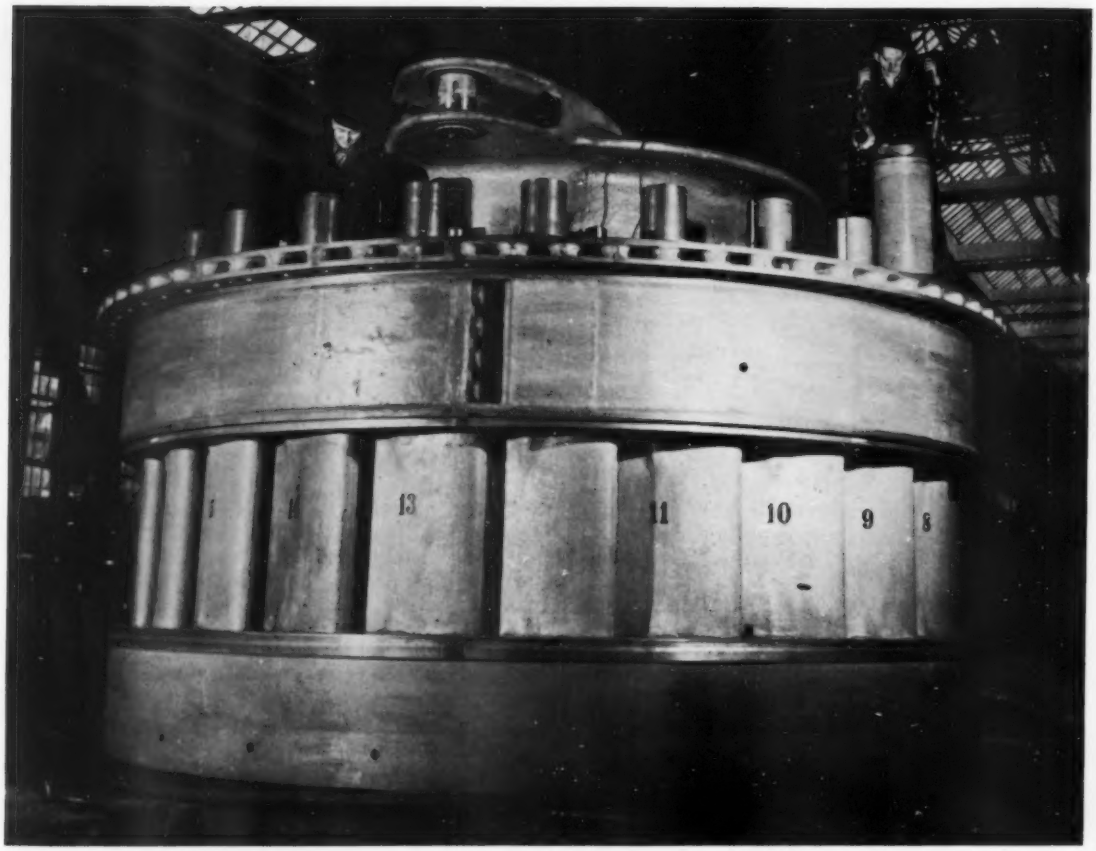


Fig. 9. Wicket-gate assembly for the first Nydqvist & Holm Harsprånget turbine

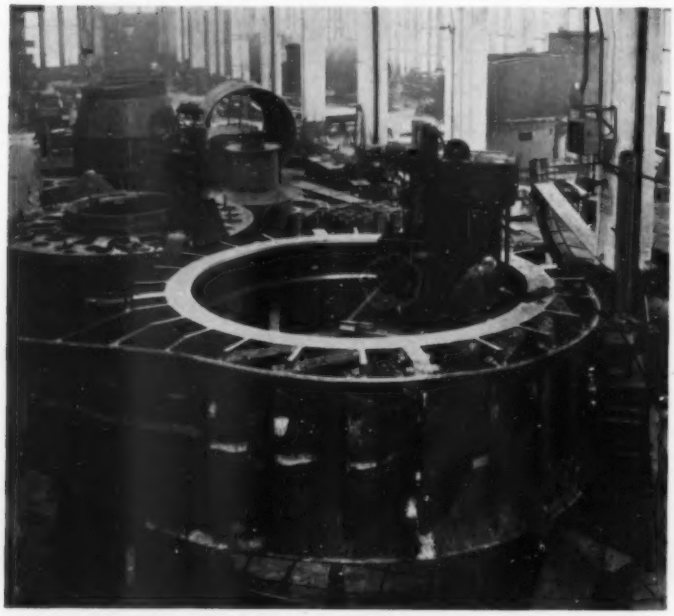


Fig. 10. Machining the stayring of one of the turbines in the Nydqvist & Holm works

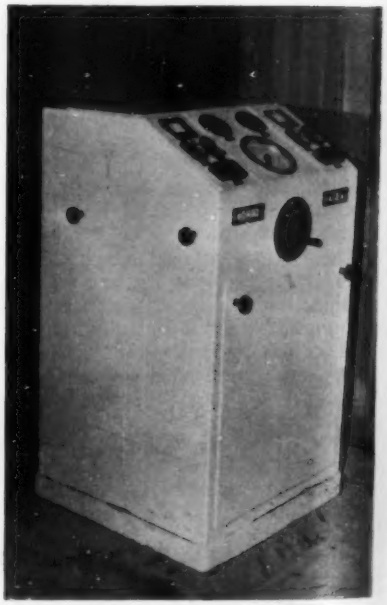


Fig. 11. Actuator cabinet for electric governing gear

turbines. An emergency spillway, with two openings, is also available adjacent to the normal spillway, these being closed by concrete slabs removed by means of a crane.

The intake, on the left-hand portion of the main dam, comprises a concrete structure in which three separate penstocks, each provided with a hydraulically operated taintor gate, are provided. These gates will be capable of being closed in ten seconds. Emergency shut-off arrangements, in the form of vertical needles, are made available, and these are operated by a revolving crane which can also be used to clear the trash racks in front of the intake.

The penstocks leading vertically down to the turbines are of special interest, since the upper portion is of a larger cross section than the lower part. This design feature is due to the fact that the upper portion is of bare rock lined with reinforced concrete only, and the lower portion is of steel tube embedded in concrete. Since the steel-tube construction is much more expensive than the concrete-lined section, only a minimum length was employed.

The machine hall is excavated from the solid rock, and allows for the installation of the three machines on the present programme. The design of the whole project, including the discharge tunnel, allows for a fourth and final machine to be installed at a later date, when further water-regulation measures, higher up the river, have made it possible to provide sufficient water. The hall is impressive in size, and the walls reveal the bare granite. It is 100 m. (328 ft.) in length and 18 m. (59·6 ft.) wide, the roof of the machine room being about 60 m. (200 ft.) below ground level. The rock above the roof is strengthened with reinforcing bars grouted into the granite. A control room, workshop, offices and other facilities are provided at one end of the machine hall.

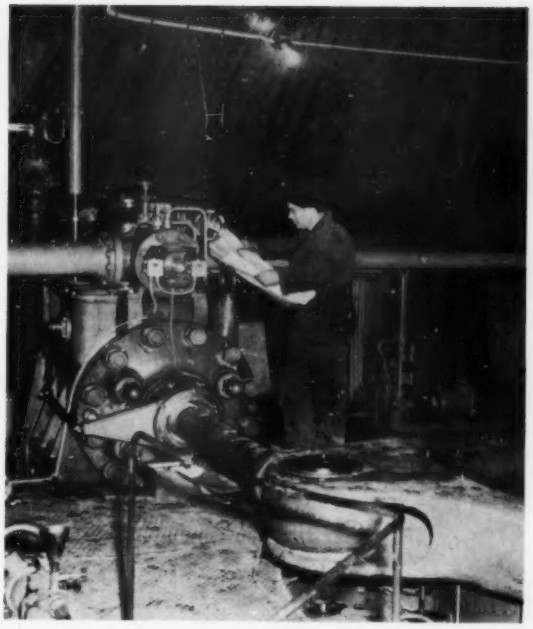


Fig. 12. Wicket-gate servomotor for the first turbine

The discharge tunnel has the very large cross section of 190 sq. m. (2,045 sq. ft.), for the first 300 m. (327 yards) from the power station. It is 22 m. (72 ft.) high and 13 m. (43 ft.) wide. The remainder of the tunnel, which has a total length of 2·9 km. (1·8 miles) is of smaller section, being 15 m. (49 ft.) in height and the same width as the first portion. The

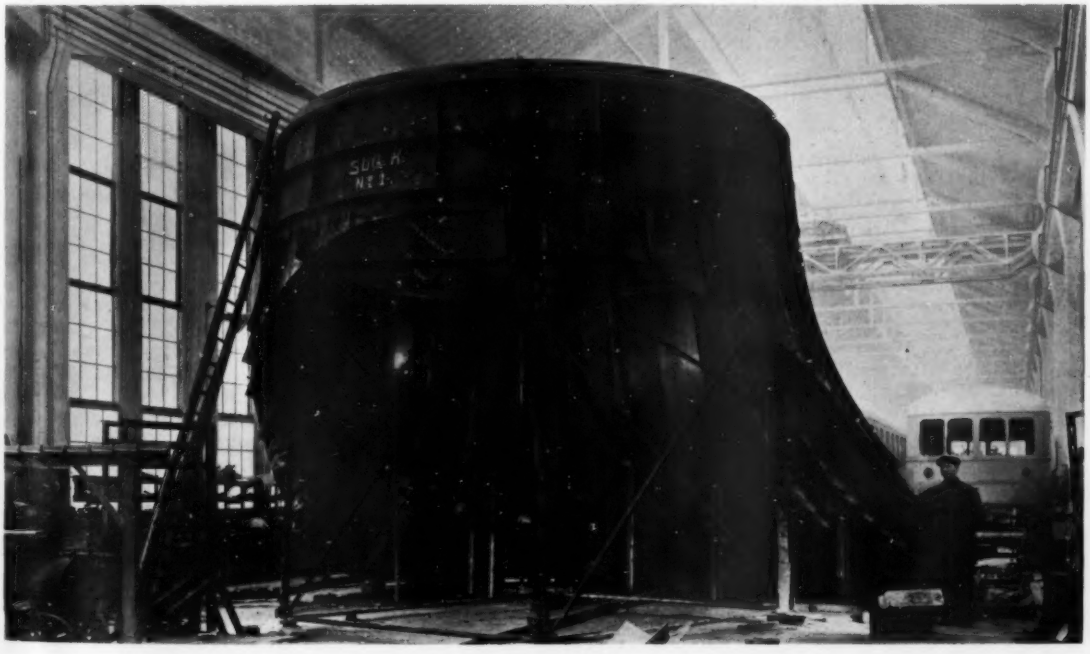


Fig. 13. Draught-tube liner in Nydqvist & Holm works

increased height in the first section provides for a surge basin.

The majority of the tunnelling and excavating work was carried out by rock-drilling equipment made by Atlas Diesel and the Sandvik Steelworks. Tungsten-carbide-tipped drills were used extensively, and for the 1¼ million cu. m. of rock excavated the cost figures per metre were the lowest yet recorded in Sweden.

Turning now to the hydraulic and electrical equipment, the turbines are of the vertical Francis type, operating under a head of 105·5 m. at 167 r.p.m. Two of the turbines were constructed by Nydqvist and Holm A.B. (N.O.H.A.B.), and one by A.B. Karlstads Mekaniska Werkstad. Steel spiral casings and fabricated steel runners are employed, with stainless-steel coating on both the runners and the gates.

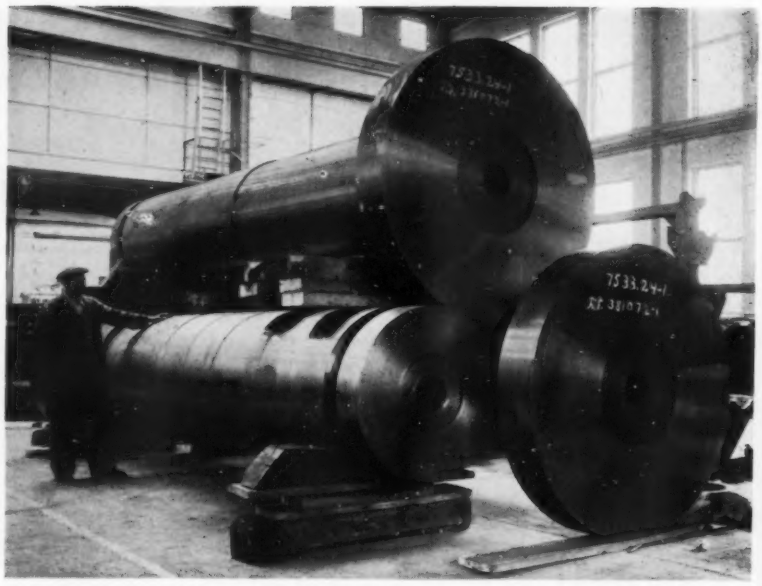


Fig. 14. The Harsprånget generator shafts in the A.S.E.A. works

The alternators were constructed by A.S.E.A., and are directly coupled to the turbine shafts. The thrust bearings are situated on the lower bearing spider of the generators and will carry a thrust load of 825 tons each. The rotor of each generator weighs 465 tons, and both the rotors and stators were assembled at Harsprånget, owing to transportation limitations.

The large size of these units meant that the stator had to be divided into six parts, instead of the usual two or four. The building of rotors on site is a technique which has been specially developed by Swedish engineers.

The rotor spider was made of two iron castings which were bolted together on site, and the core sheets were then assembled and shrunk on to the spider by the use of induction heating. In this method, single-phase a.c. current is used to feed cables wound round the rotor rings, and once the heating is complete the ring is assembled outside the spider and is then shrunk into position through the action of the natural cooling process. To facilitate construction on site, two overhead travelling cranes were provided with a total capacity of 460 tons.

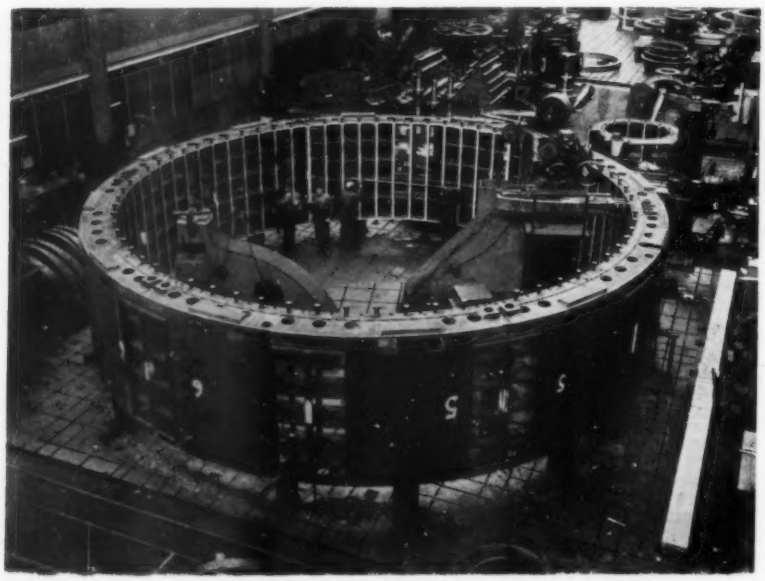


Fig. 15. The stator of one of the 96 MW generators under construction in the A.S.E.A. works

Current is generated at 16 kV 50 c/s., and taken by means of air-insulated busbars, of heavy section, to airblast circuit breakers which are understood to be among the largest in the world for operation at so low a voltage. They comprise 5,000 A 1,600 MVA units, having a making current of 150,000 A. From the breaker the power is conveyed to the transformer installation, which is also of A.S.E.A. manufacture, and is situated in a room at right angles to the main machine hall.

For dealing with the main output, the transformer arrangements consist of a single unit comprising three single-phase transformers to deal with a load of approximately 300 MW, the rating of each transformer being 115,000

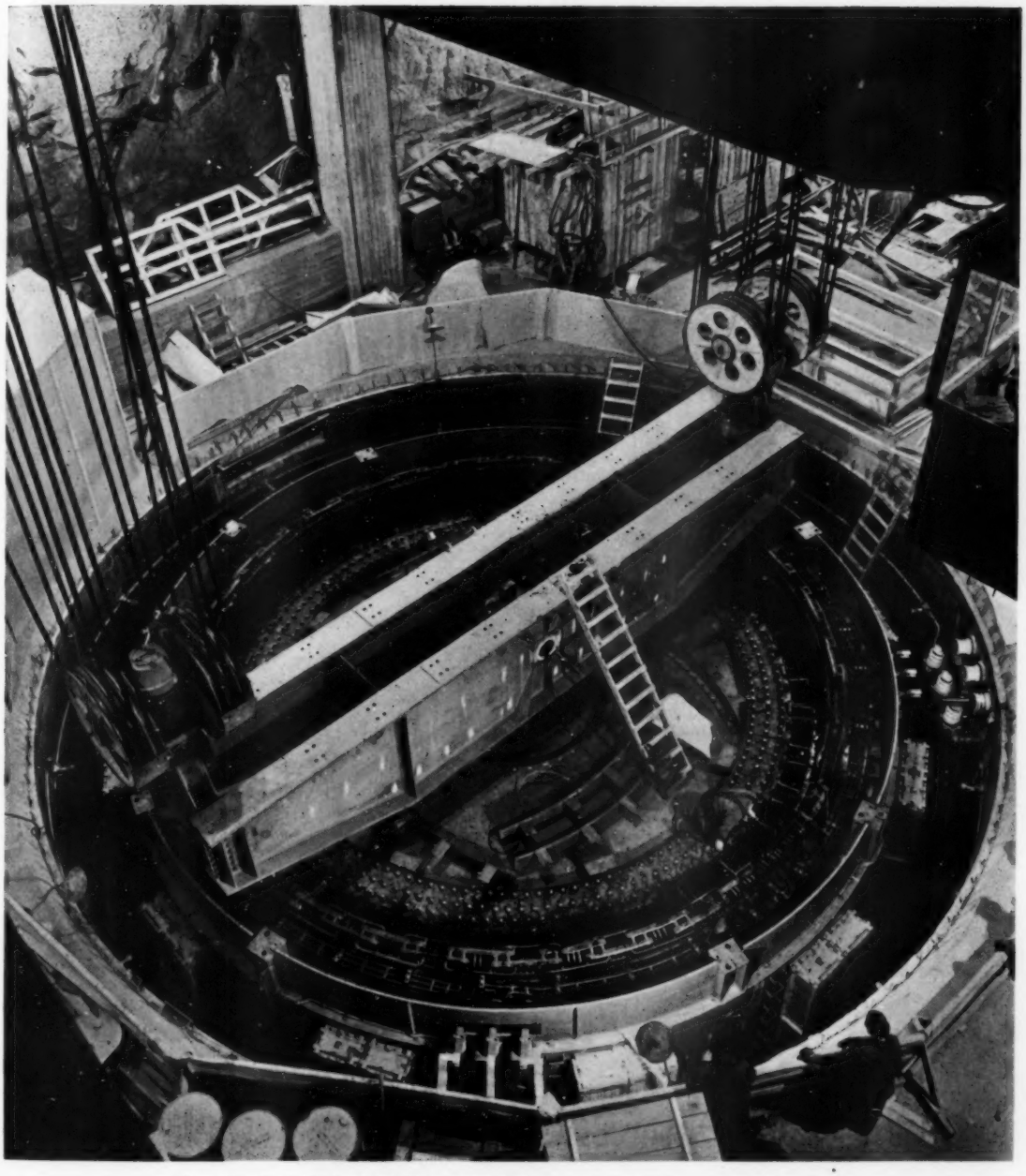


Fig. 16. One of the 96 MW A.S.E.A. generators being assembled on site

kVA. In addition, there is a spare single-phase unit, and switching arrangements have been made so that the fourth unit can be brought into action almost instantaneously in the case of a failure of any of the three running units. The transformer room also contains two 60 MVA 130 kV transformers for use in connection with local supplies in the Harsprånget district. All these units are housed in separate cells.

The transformer connections employed at Harsprånget are unique in many ways. Owing to transport limitations, a five-limb core design has been adopted for each single-phase unit. On the three inner limbs are situated three 16 kV windings and three 380 kV windings. The red phase, for example, of the first generator is connected to one of the three 16 kV windings on the red-phase unit transformer. The other two windings on this unit are connected to the red-phase connection of Nos. 2 and 3 generators respectively. Similar connections for each of the other two units, in regard to the other phases of the generators, are made.

The three 380 kV windings on each of the unit transformers are paralleled at both ends, the high-voltage side being in the centre of the winding and

taken out through the bushing to the 380 kV line connection. At the other end of the 380 kV winding, the paralleled windings are connected to a voltage regulator transformer of 9,300 kVA capacity, which is tapped on one side and is fed with energy from one of the 16 kV windings. In this way voltage regulation is obtained by means of two methods; first by natural voltage regulation of the generator itself, and secondly, by this booster arrangement, so that a very wide range of voltage on the line is obtainable. This range is necessary owing to the wide voltage variations which may be expected on such a lengthy transmission system as that employed at Harsprånget.

The capacity of the bank provides the largest transformer installation in the world, when reduced to the equivalent capacity of a three-phase unit. Cooling is by means of forced water circulation.

From the high-voltage point of the transformers the current is taken by means of 380 kV cables, which again are the first in the world to be constructed for such a voltage, carried upwards through a vertical shaft, to the termination point of the overhead line. These cables are of the oil-filled type. For the Harsprånget termination, the cables were manufactured by A.S.E.A.'s affiliated cable company, A.B. Liljeholmens Kabelfabrik, and those at the other terminating points are of Cables de Lyon manufacture.

The switching station comprises two 380 kV circuit breakers, which are of the airblast design, and have been designed and manufactured by A.S.E.A. It provides for the use of eight interrupting units, mounted vertically one above the other in a single stack, and supported on a tripod of post insulators mounted on a steel base, which, in turn, is mounted on a concrete emplacement about 0·3 m. in height. The circuit breaker, when mounted on its plinth, has the impressive overall height of 11·5 m. (about 38 ft.).

In between the legs of the tripod are situated three air pipes and the rotating insulator to operate the

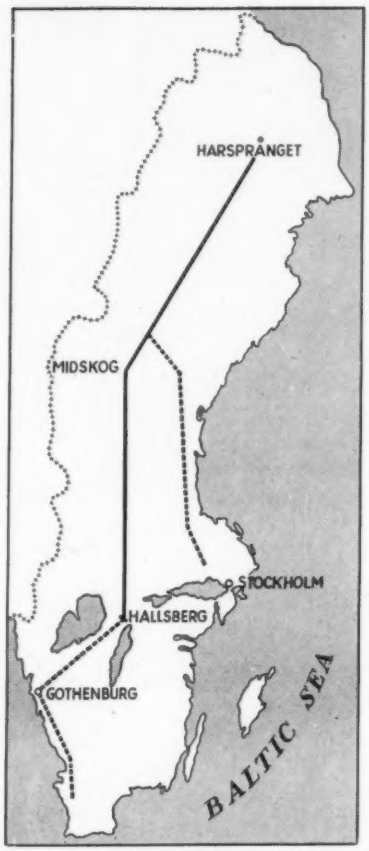


Fig. 17. Sketch map showing route of 380 kV transmission line for Harsprånget

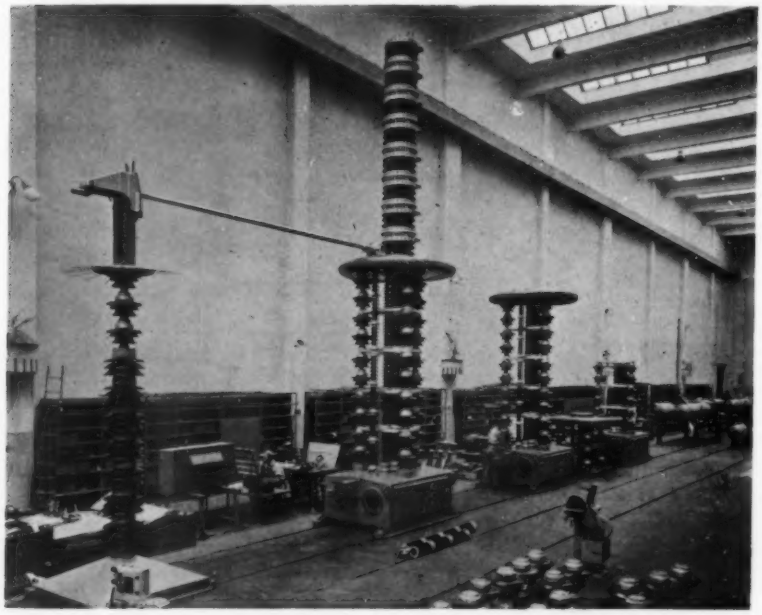


Fig. 18. A 380 kV air-blast circuit breaker in the A.S.E.A. works

make switch and the isolator blade. The isolator is used for closing, since the interrupters themselves are normally closed by the action of springs and are opened only when the blast pressure is admitted.

Between the assembly carrying the main interrupters and the post insulator supporting the remaining line contact of each phase, are situated two fabricated steel reservoirs containing compressed air at a pressure of 15 kg. per sq. centimetre, with sufficient reserve energy for a break-make - break - make - break cycle. Although single-phase reclosing is not contemplated, on account of the capacitance of the lines, the circuit breakers can be arranged for single-phase or three-phase rapid reclosing, with a dead time of not more than 5 cycles. The rated capacity of these breakers is 8,800 MVA

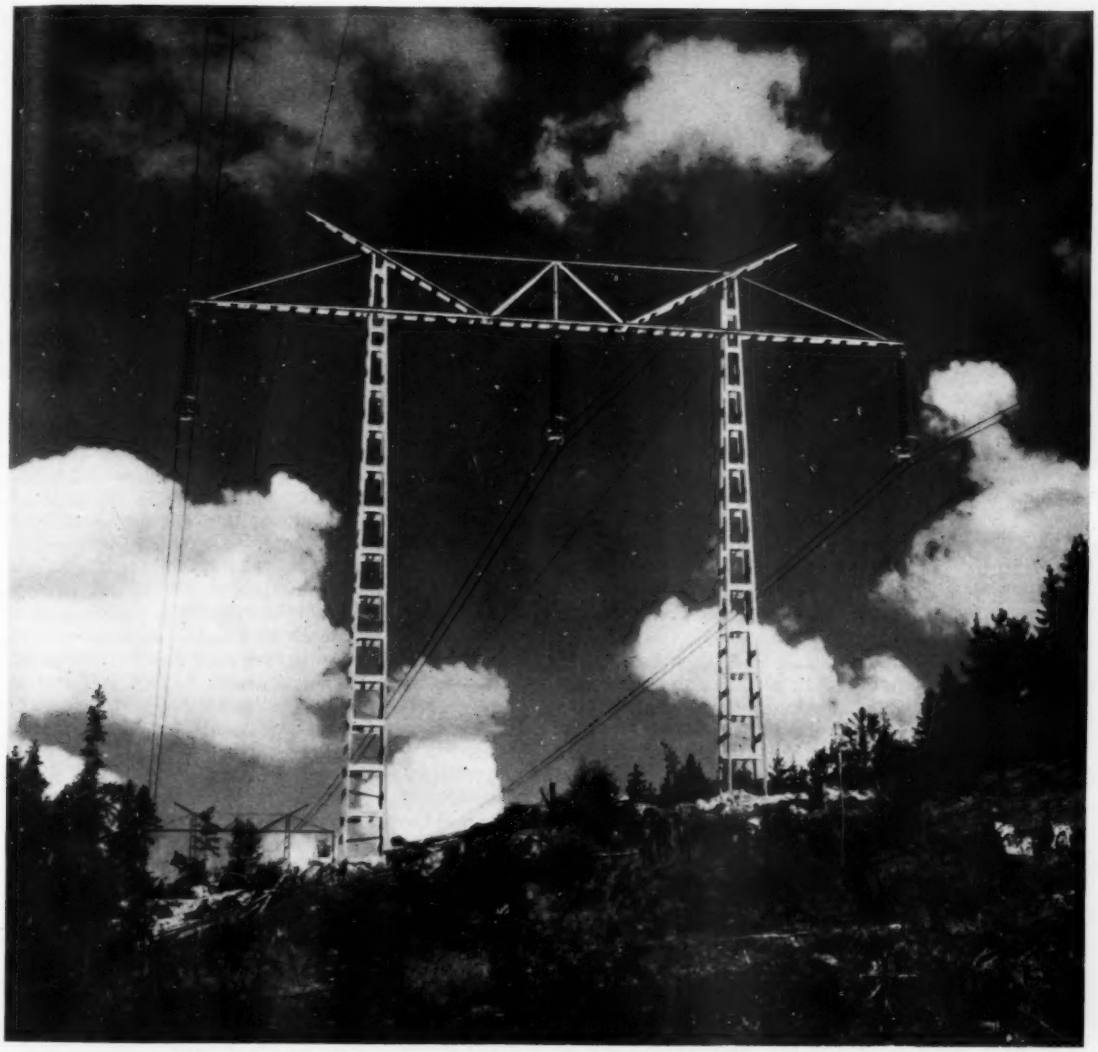


Fig. 19. Portal-type tower forming part of the 380 kV transmission line

at 380 kV. The impulse withstand level of the breakers, the transformers, and of the associated high-voltage equipment is 1,775 kV.

For the 380 kV circuit-breaking duties on some of the later of transmission lines now under construction, designs of breaker emanating from Switzerland and France are to be employed. The Brown-Boveri breaker, in which compressed air keeps the contacts apart once the circuit has been interrupted, will be used; and minimum-oil breakers made by Oerlikon and also by Sprecher and Schuh and the Ateliers de Constructions Electrique de Delle will be installed.

The single line transmitting the power to the south is made up of portal-type structures with lattice steel members, which vary in height between 19·1 and 30·3 m. (62·5 and 99 ft.). Each phase conductor comprises two steel-cored aluminium wires, each of 70 sq. mm. steel and 522 sq. mm. aluminium, spaced 45 cm. (11·71 in.) apart by means of cross-bars every 130 m. (326·5 ft.). The three-phase conductors, which are disposed horizontally, are 12 m. (39·37 ft.) apart. The average span of the line is 319 m. (1,046 ft.) between towers. Twenty porcelain or glass suspension insulators are used in each string, and two earth wires (on upward extensions of the mast, near the ends of the line, and elsewhere on top of the horizontal cross-bar) are employed. As Swedish experience on 220 kV lines, which are generally similar, is that no more than one or two faults per annum may be expected, the use of a single line is reasonable in regard to reliability. The protective gear is of the distance type, with two zones. A carrier link between the ends ensures correct discrimination.

The construction of the Harsprånget project is nearing completion, the first unit having gone into service, as mentioned above, in March of 1951. By means of temporary arrangements on the electrical side, the output of the first generator was fed at 220 kV into the 380 kV line. The line will shortly be energised at the full 380 kV, by which time all

three generating units will be available for service.

The construction of this vast project at Harsprånget, in a region where the most rigorous climatic conditions might be expected, involved the building of a complete village for those employed, and, in many cases, for their wives and families. This village, constructed of prefabricated wooden houses, providing living accommodation and other amenities, such as schools, post office, cinema, church, and the like, for a community of 2,000 souls, will, when the project is completed, be moved bodily to another site where a new hydro-electric plant is being built.

A total of 1,250,000 man-days of labour were necessary before the first unit was started, a maximum labour force of 1,300 men being employed. In spite of the utmost precautions which were taken at every stage, a total of ten fatal accidents occurred during the constructional period.

The cost of the Harsprånget project will reach a figure of approximately 230 million Swedish kroner (£15,900,000) when completed, including the transmission lines, i.e. approximately £55 per kW. It is interesting to compare this figure with the figure of £50 per kW, given recently in Great Britain, for the approximate cost of producing a thermal power plant, but excluding, in the British case, the associated transmission line. The cost of the hydro-electric development scheme alone at Harsprånget was approximately 100,000,000 kroner (£6,900,000), or £24 per kW. The whole of the Harsprånget project has comprised an engineering feat of the highest magnitude.

The author is indebted to the Swedish State Power Board, and to A.S.E.A. Limited, for the facilities they so freely extended. The photographs accompanying this article were kindly supplied by the above concerns and by Nydqvist and Holm A.B.

Book Reviews

Hydraulic Transients. *By George R. Rich. McGraw Hill Book Company Inc., New York; McGraw Hill Publishing Co. Ltd., London. 260 pp. Many ff. Price $6.10, 51s.*

Although the mathematical analysis of transient phenomena in hydraulic systems leads to differential equations which have no formal solution, they provide the basis for investigation of waterhammer and associated problems. The graphical method is favoured in Europe, but Mr. Rich concentrates on arithmetic integration and fills a distinct gap in English literature, in that it co-ordinates data that have hitherto been scattered through the journals of technical societies.

The initial studies apply conventional waterhammer theory to step-by-step calculation of the conditions prevailing in two pressure-tunnel systems when a turbine relief valve is opened or closed. Graphs relating pipeline and turbine-gate characteristics to waterhammer pressures and the Calame Gaden equations defining the subdivision of the waterhammer wave between the surge chamber and tunnel are included.

Turbine-speed regulation is influenced by runaway and waterhammer effects and the usual formulae for load demand and rejection determine maximum values but calculation of the transient speed and waterhammer phases demands successive approximation. The method is illustrated for normal closure and jammed gate conditions and the time required to load up a turbine. The forecasting of turbine performance from model tests is a feature of these studies.

The treatment of stability of turbine governing follows that developed in Gaden's "Considérations Sur Le Problème De La Stabilité," but is based on speed-responsive instead of accelerometer-type elements. This relates the regulator and waterhammer oscillations to amplitude and phase displacement between gate and head oscillations and includes the influence of governor compensation, damping, turbine type, efficiency, rapidity of damping and load characteristics. The mathematical analysis is used to establish the basic data for two stability studies including the overall effect of parallel operation, employing arithmetic integration.

Transient conditions in pumping installations following a power failure are investigated in Chapter 4. Typical centrifugal-pump characteristics for reversed rotation and flow are utilised for the case where there is no valve on the discharge side of the pump which runs backwards until the head gates are closed. The closure law for a rotary valve which will prevent waterhammer and reversed impeller rotation are subsequently ascertained. Descriptive data, diagrams and test results are presented for surge suppressors, and their limitations and dimensions defined in terms of flywheel and pipeline parameters. An arrangement drawing illustrates air-inlet valves for installation at high points in the pipeline.

Investigations of differential and restricted-orifice surge chambers follow the theoretical treatment of R. D. Johnson. One chapter is devoted to the former type and provides data for determining preliminary dimensions of the tank, riser, ports and surging limits based on friction losses, turbine performance, stability and critical velocity. The transient velocities and level variations in tank and riser accompanying instantaneous full-load demand and rejection are determined by arithmetic integration for which tabulated calculations are provided, using ports of special design based on model tests. Operating test results are given.

The design and application of restricted-orifice surge chambers is dealt with on the same lines but differential tanks seem to be preferred, because governing may become critical with the former type. An approximate relation between conduit length, area and orifice dimensions provides a rough criterion for selection of the appropriate type.

Numerical examples showing the development of the decelerating head on load rejection, suppression of synchronous load changes, stability of one tank serving two turbines, amplification of surge levels and tunnel velocities, demonstrate the value of arithmetic integration methods.

The studies of turbine speed regulation, surge-chamber and governor stability appear to disregard the influence of system interconnection and restricted orifices in relation to the free surface area fixed by the Thoma criterion. The author refers to the electric analogy in the preface but it is to be hoped that future editions will deal with this new method because it is now recognised that transient conditions in hydraulic and electrical systems are inter-related.

The conditions required for quiet filling of navigation locks are competently outlined in Chapter 7,

which emphasises the limitations of mathematical analysis and the importance of model tests, particularly for the longitudinal header system where entrance contractions and symmetrical port spacing produce non-uniform flow distribution with laterals near the lower gates discharging before those adjacent to the upper gates. These effects may disturb vessels in lockage, and for lifts of 15—30 ft. the venturi loop system is preferred where the valves ensure small initial openings and flaring outlets reduce impulse forces. Consideration of flow, mass oscillation, acceleration head, friction and related losses neglecting waterhammer and translatory motion in the chamber leads to a differential equation suitable for arithmetic integration. A numerical example with model test results is given.

Open channels feeding hydro-electric stations may be subject to sudden flow variations due to load changes while navigation channels are affected by gradual tidal changes. Both problems are analysed with numerical examples in Chapter 8. The former is based on R. D. Johnson's method where channel slope and friction are introduced as finite steps and for the latter Airy's differential equations are developed with an infinite series solution for a lock at one end and other conditions.

As former Chief Design Engineer to the Tennessee Valley Authority and Consulting Engineer to Charles T. Maine, Inc., the author has drawn on a wealth of experience for the tabulated calculations relating to important projects. These are an excellent guide to hydro-electric engineers investigating overall plant operation where the civil, mechanical and electrical phases become interrelated.

The printing, binding, indexing and bibliography, coupled with easy literary style, conform to the standards expected in the American Engineering Societies Monographs.

Design Studies for a Closed-Jet Water Tunnel.

By John F. Ripken. St. Anthony Falls Hydraulic Laboratory, Minneapolis, University of Minnesota. Price $2.00.

This paper gives a detailed account of an extensive series of design studies undertaken to formulate plans for a large variable-pressure water tunnel to be constructed by the United States Department of the Navy at the David Taylor Model Basin, Carderock, Maryland. This apparatus will be the hydraulic equivalent of a wind tunnel, and is expected to be a valuable tool in the study of cavitation and of hydrodynamic characteristics of underwater bodies. The experimental studies have been carried out at the St. Anthony Falls Hydraulic Laboratory under the general control of its Director, Dr. L. G. Straub, and under the supervision of the author. The actual water tunnel is to have a test section 5 ft. in diameter by 30 ft. long, and the studies have been carried out on a one-tenth scale model.

Although the purpose of these investigations is highly specialised—and indeed, a water tunnel of this size and type is a rare facility—so many problems were encountered of general interest to hydraulic engineers that it was felt that a full publication of the results would be of value to a wide circle of engineers throughout the world. In our view, research workers and designers concerned with hydraulic problems will be indebted to the Laboratory for this publication, for they can hardly fail to follow the paper with instruction and interest.

Each section of the apparatus—test section, contraction, diffuser, vaned elbows, and pump—has been investigated separately and is the subject of a separate chapter in the paper.

The paper is a high-quality lithographed production of upwards of 150 pages bound within paper covers, and contains numerous photographic reproductions and line diagrams.

Inauguracao do escalaon de Venda Nova

(Dedication of the Venda Nova hydro-electric plant).

This handsomely produced brochure, issued by the "Hidro-Electrica do Cavado" (Cavado Hydro-Electric Co.), describes the new Venda Nova installation on the Rabagão river, together with the projected Salamonde plant, both comprised in the Cavado-Rabagão development programme in North Portugal. Paper, print and illustrations are of the highest class; among the latter the water-colour reproduction of views of the Vila Nova dam and power plant deserves every praise.

Vocabulaire Electrotechnique International — International Electrotechnical Vocabulary.

Published by the International Electrotechnical Commission, Geneva, 1950. 11 in. × 8 in., pp. 311. Price Sw. Fr. 15.00.

This is a reprint of the first edition of the Vocabulary published in 1938. In structure it follows the lines of the well known Schlomann-Oldenburg technical dictionaries in six languages; terms are classified into groups, e.g. Fundamental Definitions, Machines and Transformers, Electro-Mechanical Applications, etc., and these groups are subdivided into sections such as, taking the first group mentioned above as a typical example: General terms, constitution of matter, electrostatics, electrokinetics, magnetism, etc. A separate index is appended for each language: French, English, German, Italian, Spanish and Esperanto.

There are many terms in the English section which will please neither the British nor the American user, since, as the result of an agreement between the National Committees of Great Britain and U.S.A., they represent more or less a literal translation of the French term.

The German section will, on the other hand, require a careful revision with the co-operation of German experts; it is difficult to find any explanation for the fact that, in at least ten instances, the German term has simply been left out.

We understand that a new revised edition of this vocabulary is in course of preparation, but even in its present form, the Electrotechnical Vocabulary will prove very useful to both technicians and students, not to mention translators who will, in cases of doubt, find the definitions attached to French and English terms very helpful.

Hydraulic Turbine Design. A general trend in turbine design is towards a reduction in overall weight and cost by use of welded plate-steel construction and by increasing the casing inlet velocities, W. J. Rheingans, manager of Allis-Chalmers' hydraulic section, told the hydraulic session during the recent annual meeting of the American Society of Mechanical Engineers in Atlantic City, New Jersey, in a paper, "Highlights of Recent Developments in Francis Turbines."

A Contribution to the Study of Butterfly Valves

By D. GADEN, Eng.

A description and discussion of reduced-scale model tests made by Ateliers des Charmilles S.A., Geneva.*

PART II

IF we consider all the diagrams of P, C and Q^2 for the same type of valve and for positions of the disc taken at 5° intervals, the following conclusions can be drawn (Figs. 15 to 20):

(1) The flow coefficient k_q in each case diminishes steadily, from a maximum obtained at $\alpha = 0°$, to zero for the closed valve. Notice that discs *A* and *B* close at 80° from full open and disc *C* at 73°. The values of k_q are practically the same with zero or vacuum back pressure. The maximum k_q is less than the theoretical value of 12·1 m./sec.² (39·7 ft./sec.²) of equation III; in fact, it is only about 45 per cent. of the theoretical value.

Values of k_q with positive back pressure are much greater than for zero or vacuum back pressure at the same angles.

(2) Where the back pressure is zero or vacuum, the force coefficient k_p increases constantly to a maximum at the closed position. This maximum is the theoretical value 786 kg./m.³ (49 lb. per cu. ft.) of equation I. For positions other than closed, k_p is slightly different in the two cases, but the difference from the theoretical, for a given disc, is always in the same direction.

For operation with positive back pressure, the coefficient k_p, on the contrary, diminishes constantly to reach the same theoretical value of 786 kg./m.³ (49 lb. per cu. ft.³) at the closed position. This change in the behaviour of the coefficient k_p would appear paradoxical at first sight, but for a true comparison with

*The results of some of these tests were published in the *Schweizer Bauzeitung* (May 21 and 28, June 4, 1938) but new data have been added to the present article.

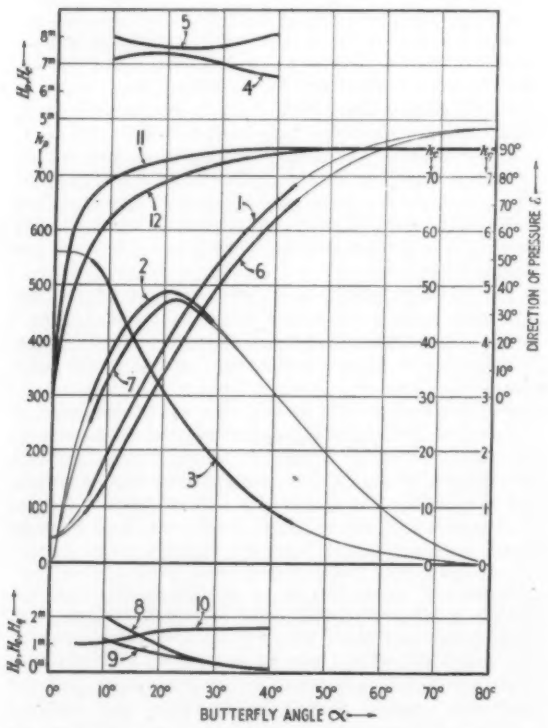


Fig. 15. Characteristic coefficients of disc A with zero back pressure

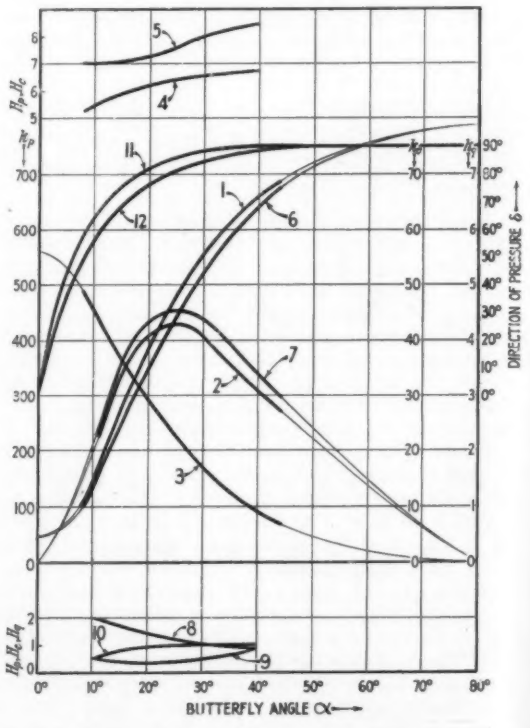


Fig. 16. Characteristic coefficients of disc B with zero back pressure

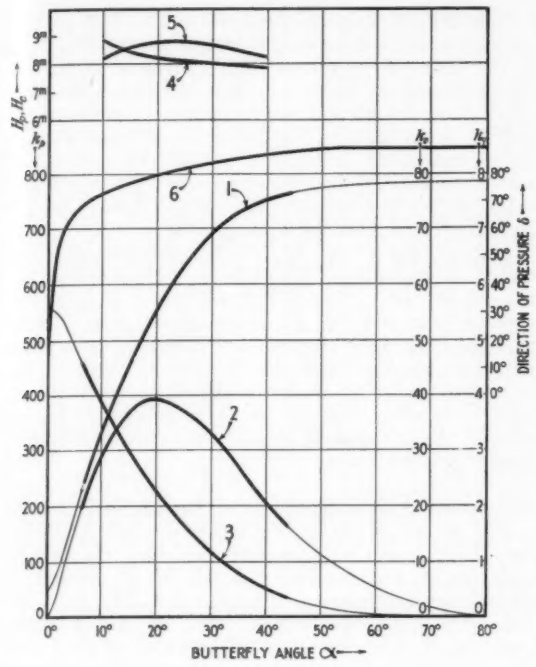


Fig. 17. Characteristic coefficients of disc C with zero back pressure

the first two cases* where the upstream pressure H is constant, we must not forget that the pressure difference in the third case: $\Delta H = \frac{Q^2}{k_q}$ increases greatly with increasing values of α. This results in the function of the force P, at constant upstream pressure H, being quite different from the function of k_p. We shall come back to this point in more detail.

The values of H_p vary a little with the angle of inclination α variation is small in the range of angles where the forces are large.

(3) For operation with zero or vacuum back pressure, the torque coefficient k_c starts to increase, reaches a maximum at the same angle in each case, and then decreases; k_c is zero with the valve full closed or full open. Between the full-open and full-closed positions, k_c is different for zero or for negative back pressure, but for a given disc this difference is always of the same sign. As in the case of H_p, the value H_c varies a little, but the variation is not large in the region where the torque is large.

The torque coefficient k_c for positive back pressure diminishes constantly, to become zero at the closed position. Here again, this change in the behaviour of k_c should not be interpreted without considering the difference of pressure, ΔH, which varies greatly with the angle.

*Note that in translating Figs. 15 to 20 into English units the formulae have been changed so that Hp, Hc, Hq are always positive quantities, to avoid errors in using the curves. Where Hp, Hc or Hq are constant, the numerical value has been introduced in the formula instead of the symbol.

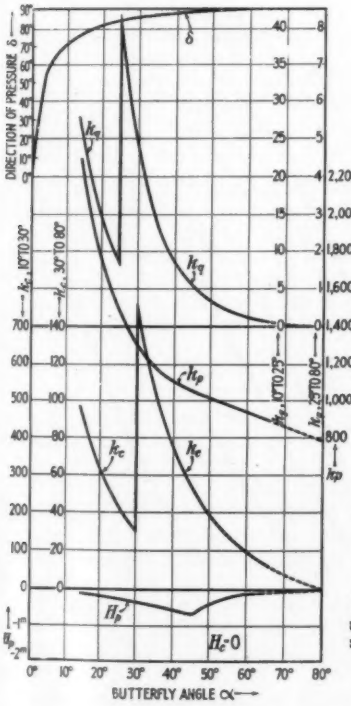


Fig. 18. Characteristic coefficients of disc A with positive back pressure

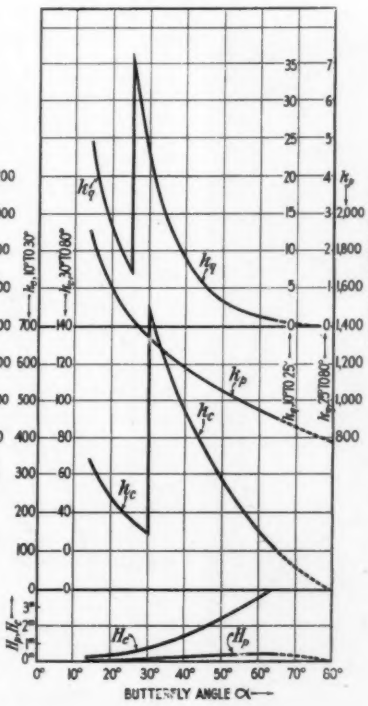


Fig. 19. Characteristic coefficients of disc B with positive back pressure

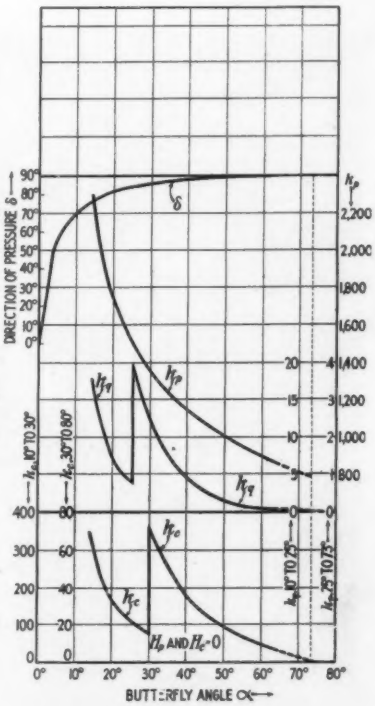


Fig. 20. Characteristic coefficients of disc C with positive back pressure

(4) The angle δ which denotes the direction of the force P with respect to the centreline of the disc, is about 90° whenever the angle α is appreciable. This is as it should be because in theory the force P should be perpendicular to the plane of symmetry of the disc if friction were neglected. The component of P in the direction of flow can be compared with the drag of a wing.

The above statements are graphically represented by the curves of:

Fig. 15 for disc *A* cases *a* and *b*
(Negative or zero back pressure)
Fig. 18 for disc *A* case *c*
(Positive back pressure)
Fig. 16 for disc *B* cases *a* and *b*
(Negative or zero back pressure)
Fig. 19 for disc *B* case *c*
(Positive back pressure)
Fig. 17 for disc *C* case *a*
(Negative back pressure)
Fig. 20 for disc *C* case *c*
(Positive back pressure)

They represent the values of k_q, k_p, k_c, H_q, H_p, H_c and δ as functions of α. These curves summarise all the results for the three methods of operation, with back pressure positive, zero, or negative (equal to vacuum).

As was indicated above, the curves for cases *a* and *b* show that the form of the disc has an effect on the angle at which the maximum torque occurs, and also on the value of this torque, which is characterised by the coefficient k_c maximum. For the types of discs studied, this coefficient is approximately between 40 and 49 kg./m.^{3} (2·5 to 3·1 lb. per cu. ft.), and should be applied in the formula $k_c\,(H - H_c)\,D^2$ with pressure H_c about −9 to −7·50 m. (−29·5 to −24·6 ft.) if the back pressure is negative, or +0·5 m. (1·64 ft.) with zero back pressure atmospheric.

Figs. 12 and 13 are two further diagrams of P, C and Q^2 as functions of the pressure, similar to Fig. 11. Fig. 11 was for a type *B* disc whereas Fig. 12 is for type *A* disc, and Fig. 13 is for type *C* disc. Notice that the fixed wall of type *C* requires a greater pressure for complete "priming." In Fig. 13 the limit for complete "priming" is about $H = 12$ m. (39·4 ft.) at $\alpha = 25°$, instead of $H = 9$ to 10 m. (about 30 ft.) at $\alpha = 30°$, for the cases of Figs. 10 and 11, which should make "priming" more difficult.

Discussion of Results: Effect of Partial Cavitation

For operation with the back pressure zero, or negative (and equal to a perfect vacuum), the results obtained, as expressed by Figs. 15, 16, 17, are immediately applicable to any practical case. The flow, the force and the torque depend only on the upstream pressure H at the entrance of the valve. If the value

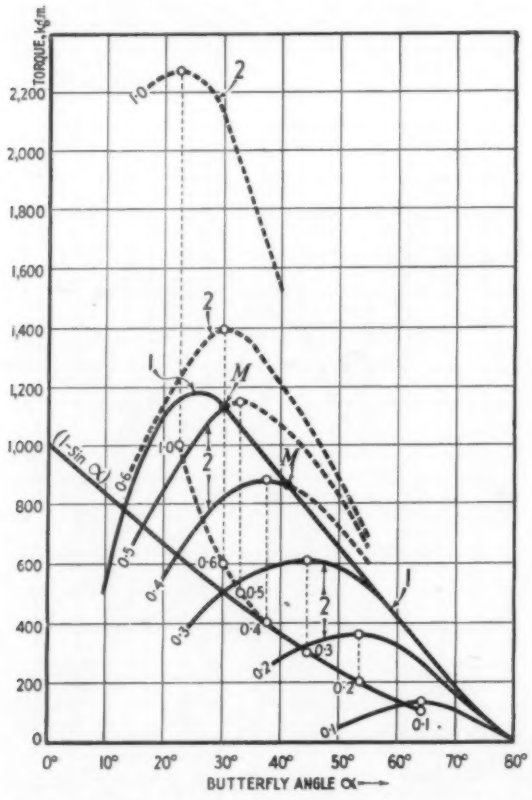


Fig. 21. First example showing torque curve for disc B.
Curve 1 = limit of torque
Curves 2 = torque for $\mu = 1{\cdot}00$ to $0{\cdot}1$
Points M = commencement of cavitation

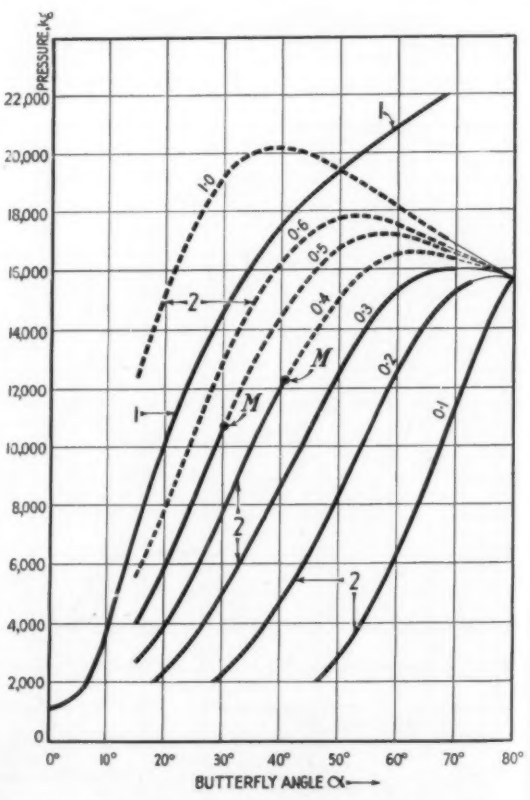


Fig. 22. First example showing pressure curves for disc B.
Curve 1 = limit of pressure
Curves 2 = pressures for $\mu = 1{\cdot}00$ to $0{\cdot}1$
Points M = commencement of cavitation

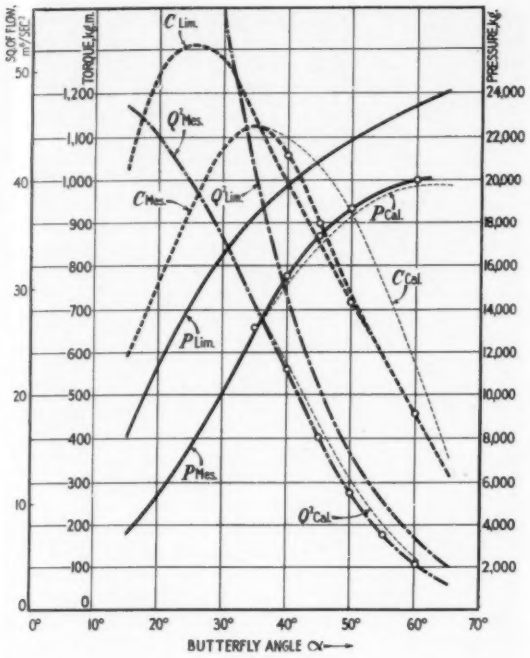


Fig. 23. Second example showing square of flow, torque and pressure curves for disc B.

P_{mes} = *measured pressure*
P_{lim} = *limit of pressure (vacuum)*
P_{cal} = *calculated pressure*
C_{mes} = *measured torque*
C_{lim} = *limit of torque*
C_{cal} = *calculated torque*
Q^2_{mes} = *measured square of discharge*
Q^2_{lim} = *limit of square of discharge*
Q^2_{cal} = *calculated square of discharge*

of H is influenced by the loss of head in the conduit a correction must be made according to the law:

$$H = H_s - \lambda Q^2$$

where H_s is the difference in level of the reservoir and the valve, and λ is a factor for head loss. If Q^2 is plotted against H, this law is shown by a straight line, as is the law of flow in the valve:

$$H = H_q + \frac{Q^2}{k_q D^4}$$

for any value of the angle α, and consequently of the coefficient k_q.

The intersection of the first line with the family corresponding to this second equation enables the determination of H as a function of α; then by means of one of the above figures the force and the torque can be calculated. It does not appear necessary to give an example.

For operation with positive back pressure, it is somewhat more difficult to find ΔH as a function of α, but it may easily be done by graphical means, as follows:

Let H_s† be the difference of level between a reservoir and a turbine (or an orifice) situated at the extremity of a conduit. Let the turbine or orifice be represented by a nozzle defined by its diameter d such that:

$$Q = \frac{\pi}{4} D^2 \mu \sqrt{2gH'} = \frac{\pi}{4} d^2 \sqrt{2gH'}$$

where D is a diameter of the valve, H' is the total pressure before the nozzle and μ is a coefficient:

$$\mu = \left(\frac{d}{D}\right)^2$$

The pressure H' is equal to the height H_s less the losses ΔH in the valve and λQ^2 in the conduit.

$$H' = H_s - \Delta H - \lambda Q^2$$

or

$$\frac{1}{2g} \cdot \frac{Q}{\frac{\pi d^2}{4}} = H_s - \Delta H - \lambda Q^2$$

or

$$Q^2 = \frac{H_s - \Delta H}{\frac{1}{\frac{\pi^2}{8} g\mu^2 D^4} + \lambda}$$

In the case where there is no conduit loss ($\lambda = 0$),

$$Q^2 = \frac{\pi^2}{8} g\mu^2 (H_s - \Delta H) D^4$$

If we plot Q^2, as defined by one of the above equations, against H we obtain a straight line intersecting with the family of straight lines:

Fig. 24. The butterfly valve for Genissiat, diameter 5,200 mm., head 75 m.

†H_s could also be the discharge head of a pump, measured above the level of the nozzle (which represents the back pressure). In this case H_s would not be constant, but would be a function of Q, complicating the calculation but not changing the principle.

$$Q^2 = k_q \Delta H D^4$$

governing the flow through the valve. The point of intersection give ΔH as a function of α or k_q. By the use of these values of ΔH and Figs. 18, 19 or 20 we can calculate the force and the torque.

Figs. 21 and 22 represent the results of calculating the torque and force in the case of a disc of type *B*, and diameter $D = 1$ m., discharging through a conduit without losses ($\lambda = 0$) through nozzles of different diameters, defined by a coefficient $\mu = 0{\cdot}1$, $0{\cdot}2$, $0{\cdot}3$, $0{\cdot}4$, $0{\cdot}5$, $0{\cdot}6$ and $1{\cdot}0$. The nozzles are a vertical distance $H_s = 20$ m. below the water level in a supply reservoir. As was predicted in the preceding section, the laws of force and torque as functions of α are completely different from those of the coefficients k_p and k_c. The large variation of ΔH gives curves of torque and force showing a maximum. This corresponds well with actual tests.

In particular, the torque curves of Fig. 21 have maxima which decrease with decreasing value of μ, that is with a decreasing value of d, the diameter of the nozzle. This is a result of the fact that the flow is less for smaller nozzles. In fact, not only is the throttling in the nozzle greater as μ diminishes, but also the maximum torque occurs at greater angles α of the disc. It is remarkable that, at least for small values of the coefficient μ, the angle α for which the torque is a maximum may be obtained from the equation:

$$\mu = 1 - \sin \alpha$$

that is to say, the maximum torque takes place when the area of the valve opening is equal to that of the nozzle. For large values of μ, the angle corresponding to the maximum torque does not decrease so quickly; the influence of the thickness of the disc becomes noticeable and the law $\mu = 1 - \sin \alpha$ no longer corresponds to reality.

The curves of torque and force of Figs. 21 and 22 would be applicable without restriction if cavitation did not occur—in other words if the depression in the restricted sections of the valve were not limited to an absolute vacuum. It is evident that this limit is reached with increasing values of the coefficient μ more quickly for large values of the upstream pressure H than for small values of H. On the other hand, we note that when the downstream depression reaches a vacuum, the force and the torque, as functions of α, obey the same laws as our tests with negative or vacuum back pressure (case *a*) for the disc *B*, see Fig. 16. Therefore, it is possible to draw the curves of force and of torque corresponding to vacuum back pressure as we have done in Figs. 21 and 22, supposing for simplification that the nozzle is situated at the same level as the valve. That is, the head on the valve, $H = 20$ m.,* is the same as the corrected static head on the nozzle, H_s.

The calculated torque curves for $\mu = 0{\cdot}1$, $0{\cdot}2$, and $0{\cdot}3$ are entirely below the curve of limiting torque, corresponding to a negative back pressure equal to an absolute vacuum, or coincide with it at very large angles. The torque curves calculated for $\mu = 0{\cdot}4$ and $0{\cdot}5$ cut the limiting torque curve about $\alpha = 41°$ and $30°$ respectively. The torque curve calculated for $= 0{\cdot}6$ and $1{\cdot}0$ are situated entirely above the limiting torque curve.

The above can be explained as follows. For small nozzles the progressive closing of the disc can take place without ever creating a vacuum downstream of the disc. Even if a vacuum is created towards the closed position, the fact that the force and the torque do not exceed the limiting valves of force and torque when the back pressure changes from positive to negative is proof that the conditions of flow remain the same in both cases and that they are not affected as they would be if complete vacuum, i.e. heavy cavitation, occurred.

For nozzles of larger diameter, such as, for example, a nozzle corresponding to $\mu = 0{\cdot}5$ in the case considered where $H_s = H = 20$ metres, the calculated torque is less than the limiting torque if the angle is less than 30°. This means that there is no cavitation at angles less than 30°, and the back pressure after

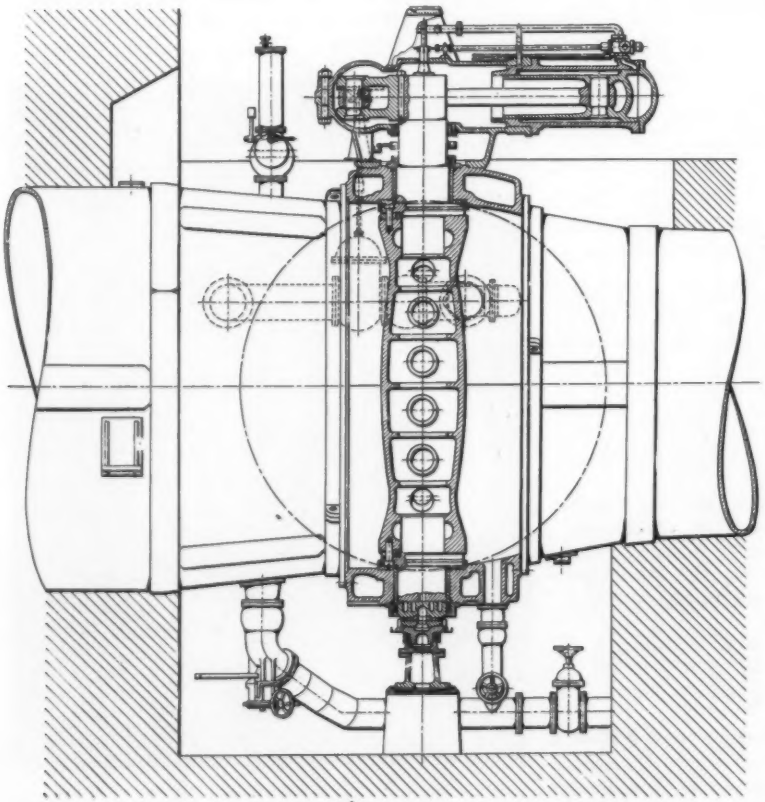


Fig. 25. Section through the Genissiat butterfly valve

*If the valve and nozzle were at different levels, the head used in the calculation of the limiting curves would differ from the head on the nozzle.

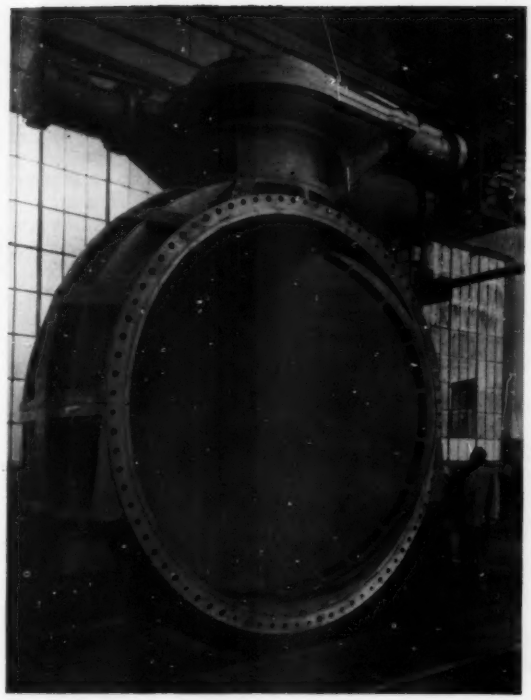


Fig. 26. Lavey butterfly valve, diameter 4,200 mm., head 43 m.

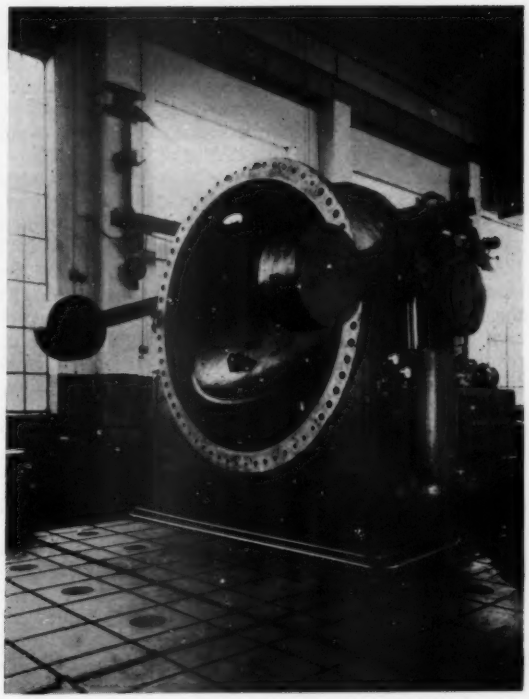


Fig. 27. Rossens safety valve, diameter 2,900 mm., head 105 m.

the disc remains unchanged whether the static back pressure is positive or negative. For $\alpha = 30°$ the calculated torque just equals the limiting torque corresponding to a negative back pressure equal to vacuum. We would, therefore, be tempted to say that the vacuum is really established on the downstream side of the disc and that, a greater depression being impossible, the torque cannot exceed the limiting torque of case *a* corresponding to complete vacuum. The calculated torque, shown by the dotted line, should therefore not be considered, and only the limiting torque is valid. We shall show later that actually the true torque can be somewhat greater than the theoretical limiting torque.

For very large nozzles, corresponding in our example to $\mu = 0{\cdot}6$ and $1{\cdot}0$, complete cavitation is established at small angles. Only the limiting torque curve should therefore be considered and the calculated torque curves are quite fictitious, for they make no allowance for the fact that it is impossible to have a depression greater than the barometric pressure. These curves could be of no interest unless the system were in a high-pressure atmosphere, which would permit the depression after the disc to fall below the pressure at the exit of the pipe by a greater amount than the usual barometric pressure H_b.

In order to examine, in more detail, this transition from operation without cavitation to operation with cavitation, we show in Fig. 23 a second example, calculated for conditions corresponding exactly to one of our test conditions. In this case, disc *B* was used under a head $H = H_s = 23{\cdot}30$ metres (76·4 ft.) discharging through a nozzle giving $\mu = 0{\cdot}4285$. Figures for different diameters have been transposed to a disc diameter $D = 1$ m. Curves of the square of the flow Q^2, the force *P*, and the torque *C* are shown in Fig. 23:

(1) For complete cavitation, that is to say, with a negative back pressure equal to a vacuum.

(2) For values calculated without cavitation, that is to say, with back pressure either positive or negative, but without considering the fact that the back pressure cannot fall below a vacuum.

(3) For values actually measured on tests. The values differ from the calculated values in the direction indicated above.

Examination of Fig. 23 leads to the following conclusions: The calculated torque curve cuts the limiting curve at $\alpha = 35°$. According to our conclusions above, this is the position which should correspond to the establishment of a vacuum, or complete cavitation. This assumption is not fully confirmed because at $\alpha = 35°$ the measured flow is still equal to the calculated flow and considerably less than the limiting flow $Q^2 = 40{\cdot}3$ m.^{6} per sec.^{2}. However, beyond 35° the measured flow is less than the flow calculated without limiting the depression to a vacuum. In other words, at $\alpha = 35°$ there is only a beginning of cavitation.

If this region of partial cavitation causes a torque at 35° equal to the limiting torque, in spite of the fact that the flow is less than the limiting flow, this is probably because, as was predicted above, the pressure distribution on the back of the disc is different from that occurring with total cavitation, the difference being such as to cause a torque greater than the limiting torque for the same value of *Q*.

For increasing values of the angle α the condition of partial cavitation continues. The measured flow becomes less than the calculated flow, which is in turn

less than the limiting flow. The measured torque departs from the calculated torque, but even so it becomes greater than the theoretical limiting torque. The measured torque approaches the limiting torque again when the angle α becomes larger and the effect on torque of partial cavitation is the same as the effect of total cavitation, in spite of the difference in flow. The measured force is greater than the calculated force at angles above 35° and remains greater, although it does not reach the limiting force, which would correspond to a considerably greater flow.

Under conditions of partial cavitation, where the calculated torque can no longer be considered, the measured torque reaches a maximum of 8 to 10 per cent. greater than the theoretical limiting torque. This result is deduced from the example in Fig. 23 and from several similar tests comparing actual values with those calculated. For practical purposes we think it reasonable to neglect the fact that the measured torque is somewhat greater than the theoretical limiting torque, because the difference is generally no greater than other indeterminate factors which have to be allowed for in design.

Such then, are the results of our investigations under conditions of partial cavitation, that is, conditions intermediate between the case *c*, with either positive or negative back pressure, but no discontinuity in the flow, and the case *a* of a negative back pressure equal to a vacuum. This intermediate condition between partial "priming" and full "priming" corresponds to the transition between valves of the first class and those of the second class, functioning with an absolute vacuum established downstream.

Conclusions

The tests described above were repeated on various occasions with different types of discs and different shapes of the valve body. The test equipment and particularly the measuring instruments were improved so that it is now possible to record graphically both the forces and the torque. These later tests, renewed in connection with the construction of very important valves, have confirmed the results obtained with the original tests and have shown that the type and thickness of the disc, for example, has not a determining influence on the discharge, forces or torque.

We would refer the reader for example to a paper published in the *Revue Génerale de l'Hydraulique* No. 42 (November-December 1947) regarding the reduced-scale model tests of the 5,200 mm. diameter butterfly valves under 7,417 m. static head supplied by Alsthom-Charmilles for the 98,000 h.p. turbines of the Génissiat power plant (Fig. 24). This publication shows that, in comparison with the disc type *A*, the discharge coefficient k_q is approximately 2 per cent. smaller (due to a relatively thicker disc), and that, the force coefficient k_p remains practically unchanged. The torque coefficient k_c is more sensitive to variations in the shape of the disc and body and shows an increase of about 9 per cent. for which the thicker disc and the converging body of the Génissiat valve, as shown on Fig. 25, can be held responsible.

Serious accidents have occurred on more than one occasion owing to an under-estimation of the forces and of the torque to which the disc of a butterfly valve is subjected while closing against the full head and discharge of the installation. With the test results given above, each owner of a butterfly valve can, with ease and speed, calculate with a reasonable exactitude the forces and the torque that will arise if his valve ever has to close under emergency conditions, and ascertain whether the strength of the valve and of the operating mechanism is sufficient to stand up to these forces and torque without unduly stressing the material, and can eventually take remedial action. And if thereby further serious accidents can be avoided, the publication of these tests in WATER POWER will not have been worthless.

Correspondence

Analysis of Stress in Flanges for Turbine Pipe-flanges

To the Editor of WATER POWER

In answer to Mr. Charlton's letter regarding the above mentioned article in the October issue of WATER POWER, I am below dealing with the matters raised one by one.

(1) The flange ring drawn in dotted lines in Fig. 1 was made merely for the purpose of showing the position and the angle after the application of forces. It is assumed that the ring section rotates through a small angle ϕ about a point on the neutral axis. In strict conformity with this assumption the inner dotted line should of course cross the middle plane of the ring at a distance r_0 from the centre, thereby showing equal compression and tension on both sides of the neutral axis.

(2) I regret it is not clearly specified that the external couple M in equation 2 represents the couple per unit *angle*. In the equations 3 and 4 M denotes the moment per unit *length* of the bore as stated on page 336.

(3) Regarding the equation 6 I refer to the derivation made by Timoshenko in the book "Applied Elasticity" by S. Timoshenko and I. M. Lessels equations 107 and 108 page 140. Furthermore I can also refer to a perhaps more comprehensive derivation made by M. Ten Bosch in "Schweizerische Bauzeitung" (1940) page 133 and 134.

(4) The equation 11 can also be written as follows: $M_0 = \sigma_0 W$, where W denotes the section modulus of an element of the pipewall. As M_0 represents the moment per unit length of the bore we have $W = \frac{1 \times s_1^2}{6}$. The equation 11 can also be represented in the following form:

$$2\pi r_0 M_0 = \sigma_0 \frac{2\pi r_0 s_1^2}{6}$$

from which

$$M_0 = \frac{\sigma_0 s_1^2}{6}.$$

GUNNAR ENGLESSON.

Design of Steel Beams. The British Constructional Steelwork Association, Artillery House, Westminster, S.W.1, has published a technical brochure entitled "The Application of the Plastic Theory to the Design of Mild-Steel Beams and Rigid Frames."

Preliminary Survey for Hydro-Electric Development

By E. A. Logan, M.Sc., M.I.C.E., M.I.Mech.E., M.I.E.E., lately Chief Engineer and Manager of the Electricity Supply Department of the Government of the Union of Burma and Secretary to the Hydro-Electric Development Board.

THERE is considerable literature on the construction of hydro-electric works, but if we may hazard that for every scheme finally constructed there are in all probability ten tentative schemes considered and rejected, this literature does not give a balanced picture. It is easier to speak of achievement than of conjecture. Nevertheless, there must be a great deal of conjecture before any scheme of works is embarked upon, and the time involved may be considerably more than the time needed for construction of the works. It may be appropriate, therefore, to consider how time is necessarily spent before specifications for a hydro-electric scheme can be prepared, because by throwing light on this part of the work, valuable time may be saved on other schemes in the future.

The Origin of a Hydro-Electric Development

With the growth of knowledge of the means of development, and above all, of the need for development, more attention has been given to remote sources of power. A plan to embark upon hydro-electric development usually starts many years before there is the slightest possibility of any practical development. It may be known that there is a large volume of water in the form of a lake or a river. People talk, letters appear in the Press, other countries industrialise on a basis of water power, and a public opinion is in process of being formed. Private individuals, some mere cranks, some with a right to their opinions, prepare schemes, write papers and discuss possible projects. Some public impatience may be shown that nothing is being done to develop potential water resources. There may be indignation that existing industry is having to pay dearly for electric power while there is unlimited "free" power being nefariously withheld from the people who have a right to enjoy it. Official apathy in a matter of this sort is likely to change into a spate of indiscriminate enthusiasm. Just as undirected power may be a danger, so this new enthusiasm may be a danger to the proper rational development of hydro-electric power, which requires time and proper direction. Whereas the previous approach may have been characterised by too much restraint, the new circumstances may evidence a degree of precipitancy that may well exhaust itself before achieving any useful result. It is not usually realised how much time must properly be spent on initial work before it is possible to start outlining the major aspects of the development, let alone approach details of specification or commence construction, and it is in terms of commencing construction with early completion that the popular mind concerns itself.

Hydro-Electric Development is a Matter that Concerns Governments

At this date most large hydro-electric works are initiated by governments, and it is not hard to see why this should be so. Undeveloped power now lies mostly in inaccessible spots. The need to provide large blocks of capital, unremunerative over many years, to match the proposed power output with schemes for power utilisation, to find the solution of problems of adverse geography and politics, combine to make development possible only by an organisation having simultaneous control of all these factors—in a word, by a government.

Future Zones of Hydro-Electric Development

The present industrial countries of the world lie in the temperate zone. The fortunate accident of the occurrence of workable coal at the disposal of inventive and active peoples has led to this result. The coal is becoming exhausted, however, and more expensive to produce. But nations are seeking to extend the fruitful results of their invention to save labour and to promote amenity. This demands more power, and in the absence of further sources of coal this must be water power. The water-power resources of the temperate zones are strictly limited and not adequate to replace more than a fraction of the present thermal power development. The power engineers of the temperate zones are, therefore, having to look for lands where there is ample rainfall and where the country is rugged, to provide for the needs of water storage and working head. Attention has turned to the Arctic regions, where the potentialities are limited, and to tropical regions, where there is clearly very great scope. The great future of hydro-power development does, in fact, lie in the tropics where high evaporation rates induce torrential rain and where the hill and valley formations necessary for catchment, impounding and head exist. It is precisely these features of these lands, coupled with high temperatures and poor health records which have militated against their development. Now that power has a value of its own, wherever it may be situated, and now that the adverse effects of climate and disease may be overcome by modern science, the possibility of large-scale development of water power in tropical regions seems assured. Indeed, it seems fair to predict something in the nature of a dignified gold-rush to secure control of tropical power areas in the decades to come, if the somewhat nebulous promise of alternative sources of power to replace thermal power does not materialise.

Assessment of Potentialities by the Engineer

It is inevitable that schemes will have been widely discussed by non-experts before the expert is called in. There may be much wrong thinking to correct. Popular demand may be for a scheme staggering in immensity but unrelated to practical needs. Fruition in two to three years may be visualised. Probably, if the difficulties and the time scale were to be realised at the outset, there would be a tendency to do nothing about development. The function of the advising engineer is to divert this psychic energy into profitable channels. To do this, it is clearly not wise to attempt to arrest the flow in the direction in which it is going, but rather to seek to deflect it in a useful direction.

In the tropics, a usual geographic condition is an alluvial plain devoted to rice cultivation with large meandering masses of water subject to wide variations of flow. The volumes of water involved may be immense, even in the dry-weather period, but the rate of fall of the stream bed is low, making development of such streams very difficult and potentially costly. Such development of necessity will have to be of a multi-purpose character and have to wait until the general economy of the country can pay for the major works involved. The difficulties of developing single-purpose schemes are sufficiently great without having to tackle a major multi-purpose scheme as the first objective. In any event, large blocks of available power are necessary to make the construction of such large-scale works possible. But as the mass of people, including the persons of influence and members of the government, live on the plains beside the large rivers, it is the development of these large rivers that is first suggested.

High-Voltage Power Transmission

Power is required in increasing amounts in the densely populated zones in the plains. The saucer formation of the country results in the collection of large quantities of water with no potential energy content in the plains, whereas the power production areas are round the rim of the saucer, remote from populations and activities concentrated at the centre. The solution of this problem has resulted from the development, over the last two decades, of high-voltage transmission in reliable and economic forms. The next twenty years will result in further development of economic forms of transmission with consequent extension of the potential zone of power exploitation. Coupled with the extension of the range of transmission there will be extension of the possibility of taking the power-using industry to the point of power development. Both these tendencies will speed up development.

Purpose of Preliminary Survey

A preliminary survey of a projected scheme of hydro-electric development is undertaken for the purpose of ascertaining whether there is, in fact, an area, as the map appears to indicate, which can profitably be developed to supply hydro-electric power; the possibility of quickly establishing a motorable road connected with the main road or railway system of the country; the upper and lower limits of the water flow; the approximate head that can be developed; the general geology of the area; the possibilities of the area for providing and supporting a labour force; the health aspects of the area and the probable length of the working season if subject to extreme climatic conditions. This programme does not imply any deep or intensive specialised work, but it does demand the presence of an experienced specialist in each aspect of work involved; otherwise some factor in the future development may easily be overlooked with costly or disastrous consequences later.

Collection of Information prior to making Preliminary Survey

The more easily developed schemes, as we have seen, are in the hills overlooking the plains. The first step is to examine the potential load-consuming area and to decide upon the probable extent of the demand. Since demand for electricity is essentially elastic, too precise attention need not be given to this. Experience shows that whatever figure is forecast, the reality is likely to exceed the estimated demand many times before the plant to supply it is in operation. But the best estimate should be made to avoid the gross error of wasting valuable time in looking into developments that are much too small or much too large. Having arrived at an estimate of power needs, an assessment can be made of the nearest area at all likely to contain terrain suitable for such power production. The estimate of power requirement has two elements, maximum demand and total units. The maximum demand determines the amount of plant that must be installed to allow for plant maintenance and outages; the number of units required must be balanced by considerations of available water flow and storage, principally the latter. The number of units per annum can be converted into any convenient water equivalent such as acre feet times head, per annum. In passing, it may be remarked that the time is ripe for introducing a name into hydro-engineering for this quantity. If it already exists, the author regrets that he does not know of it. Rainfall figures of a general sort are no doubt available for the potential area. The general height above sea level of the major valleys can be ascertained from maps. A forecast of catchment area and storage area becomes possible. The scrutiny of maps and the fining down of the available data can continue side by side, each new circumstance, as it arises, being allowed to modify the direction of approach to a solution. It is possible that there may be one potential scheme clearly demanding investigation after only a short investigation, or there may be competing schemes or portions of schemes capable of integration into a single scheme. These are matters that increase the interest of this type of work and demand the greatest degree of initiative and judgment for successful economic solution. The possible variations are so great that it is impossible to generalise.

Potential Development Areas are difficult of access

A sweeping generalisation can be made, however, in saying that potential development areas are difficult of access. Apart from small-scale agriculture, there may be little economic activity in these hill regions, so that, excepting foot traffic paths, there are no roads and no established communications, simply because it has not paid anyone to establish them. It is likely, however, that the continuation of such a state of affairs is attractive to the hill dwellers and they will seek, in what they believe to be their best interests, to perpetuate it.

All information possible relating to the chosen area

should be collected. Books of travel, reports of land and Forestry officers or missionaries, are possible sources of information, and all information has a value, even if this value is not apparent at the time.

Air Reconnaissance

Aviation has placed many new possibilities at the disposal of the explorer, and hydro-electric survey, in the initial stages, may surely rank as exploration. If at all possible, an aerial journey should be made over the area in advance of the survey on foot. This is likely to save a great deal more than it costs. If good photographs can be secured from the air, so much the better. Although maps of the area may exist, experience shows that in the matter of details of contours and river courses they are likely to be more sketchy than accurate, and the overhead survey, before the ground survey on foot, is likely to reveal the more gross of the errors. In the future, it is likely that air transport and photography will play an increasing part in this form of survey, at all stages, and it is given as a firm opinion that the expense, however great it may appear, is usually handsomely justified.

An aerial survey has a good propaganda value and adds considerably to the local prestige of the subsequent survey party on foot.

A further use for aircraft has been suggested, but not, so far as is known, actually put into use. A great difficulty in making surveys in tropical hill country is to see anything at all of the country due to the height and density of the jungle of scrub or bamboo. This is costly to clear for sight lines or for road making. It has been suggested that the jungle could be burned off along appropriate lines by laying down incendiaries from the air, after giving the village headmen notice of the intention and evacuating the few persons concerned. This may appear a wasteful procedure, but the material involved is of no commercial value and is soon replaced by new growth. The time taken and the cost of removal constitutes a major item of expense in making a hydro survey. In any instance, fires of natural occurrence, or to promote clearance for agriculture, are common enough but cannot be relied upon to furnish more than a minute fraction of the total clearance needed.

Public relations

It has been pointed out that the local populace will resent any invasion of their privacy. The lengths to which they may go to resist will depend upon the extent to which the power of constituted government runs in the area, the fear of possible adverse change in their circumstances and the aggressive means they can command. It may be possible to ignore local opinion if the government is powerful and local subversive force is weak or non-existent. In the usual circumstances of a scanty local economy and resultant defective communications, it will be difficult and costly to outface local force, so that it is necessary to proceed by securing goodwill and co-operation.

To this end every effort must be made to allay fears, however fantastic and unrelated to reality they may appear. Continual effort is necessary as local opinion may be subject to day-by-day changes. This is a matter requiring the exercise of tact. Information should be sought on local customs—for example, burial rites and sites, and hunting traditions—and such information should be applied in season and with respect for the beliefs and habits of the inhabitants.

Preparations for an initial survey

Although much general information may have been gleaned by the methods already outlined, an actual site survey by specialists in their several fields of knowledge is necessary at an early stage, to ascertain if the tentatively selected development area has, in fact, the anticipated characteristics, or whether there are insuperable unforeseen difficulties. Apart, too, from proving the feasibility of properly balanced potential power development, the availability of the large quantities of natural materials necessary for construction works and access roads must be investigated. In general, the object of the initial reconnaissance is to ascertain whether it is worth while proceeding with expenditure on a full-scale survey. This must be made clear to the promoters of the scheme, who otherwise may expect that the next stage to follow the initial survey will be active construction of the works.

The basic problem of a preliminary survey is to secure the physical attendance of half-a-dozen experts of various sorts for a period of two to four weeks and maintain them in good health and spirits in a tract of country that is devoid of civilised means of communication and of which the inhabitants may be potentially hostile. The experts are probably middle-aged and of normally sedentary habits. Surprisingly enough, it is usually not difficult to secure their enthusiastic co-operation; the difficulty is to divorce them from other urgent work for the necessary period.

To avoid causing a local increase of prices and on account of the difficulties of being sure, on this first visit, of being able to purchase foodstuffs at the point of departure of the march, and the even greater difficulty of knowing whether it will be possible to buy such things as fish or vegetables along the line of march, plans should be made to provide every article needed over the whole period of the visit. Much help can be secured from army handbooks which give scales of food allowances for provisioning expeditions of this nature. A point to remember is that the number of carriers is determined by the quantity of food to be carried, and much of the food carried is for the carriers themselves.

Health and Hygiene

Experts are costly to secure and of greatly diminished usefulness if they are not kept functioning healthily every moment of the survey. The whole object of the exercise is to get them there, to see the maximum in the time available, to return them safely and receive their reports in the minimum of time. The two main short-term problems are dysentery and malaria. By taking an experienced cook and supplying clean food, it is largely possible to avoid dysentery. The party should be in and out of the area within fourteen days so that actual incapacity due to malaria should not arise. Even so, a doctor is essential. Dysentery is not so easily avoided, and without proper treatment the effects can be much more serious than mere incapacity to work.

The presence of a doctor is a guarantee of physical efficiency and comfort for the party; he must plan the health programme of future operations and he is the principal public relations officer of the party. A good doctor is well received anywhere in the world and is the best agent for peaceful penetration. If it is

possible to secure a doctor with knowledge of the people, the country and the language, so much the better.

Camping and Equipment

Most centres of population are well stocked with service equipment for camping. Previous experience is of great assistance in making a choice of such things as tents, cooking equipment and other camping material. The tendency is to select too much initially, but the important thing is to make the final departure on the actual route of the march with a bare but complete minimum of necessities. An example of a mistake made on an early expedition was the provision of tentage for carriers. It was found later that within a few minutes of arrival at a new overnight camping site they quickly erected satisfactory bamboo sleeping shelters. using no other equipment than their customary long knife. On the other hand, the lack of sufficient salt may cause carriers to desert. Equally, ability to give a bonus issue of some small luxury may be a great help in time of trouble. For persons who have become unaccustomed to hard physical effort, sugar provided on a generous scale will be found to relieve fatigue. A quantity of strong and very sweet cocoa, normally repugnant, may be found very acceptable at mid-day when there has been a long morning of hard travelling and an equally strenuous afternoon to look forward to. Hessian cloth of the type used for gunny sacks has been found valuable for packing goods for transport. Pressure paraffin lamps give a good light for writing notes after the early tropical nightfall.

Carriers and other Transport

A general feature of the type of country to be explored is an absence of ways for wheeled transport. There may be other local methods of transport such as mules, donkeys, elephants, or oxen, and the use of these must be taken into account as they have the great advantage of being able to find fodder along the route of the march. To an engineer, the loads they carry may appear disappointingly small. The load carried by an elephant seems small compared with its bulk, but one elephant may substitute six or ten carriers, or more if the saving of the food for the carriers is considered against the food required for the two elephant boys. Foot carriers should preferably be selected from men who live in the tract of country or who are acceptable to the people who live there. The use of local carriers will help to gain confidence by helping the local economy. Opportunity may be taken to enlarge on the possibilities of the prospect of further profitable employment on a wider scale in the future — a valuable means of securing cheerful obedience in the present. In addition, the dangerous element of mystery in the purpose of the expedition is largely removed, as it becomes subject to inspection and report by the carriers back to their peoples at all times.

Camp Discipline

Even in remote parts, there is now a familiarity with army ways, so that many things which otherwise would have to be regulated in detail fall into place from previous experience. Some minor local notable may come forward to act as interpreter and to organise the carriers, possibly having had previous service experience. He may be acting for the local community and reporting back to them, but that is not of any detriment to the purposes of the expedition. Some consultation may be necessary with him before setting out as to the size of loads and the scale of issue of rations. Once these are decided, clearly a strong line will have to be taken about retaining them once the march commences. It is as well to be as frank as circumstances permit about proposals for route, possible camping points and duration of stay at each camping point. Frankness pays to the extent that valuable counter suggestions may be forthcoming as to places to see or places to avoid.

Stores should be issued only by one thoroughly trustworthy individual, and should be checked as often as possible by the most senior member of the party. Definite programmes of travel and work should be laid down as early as possible and as many people as possible kept informed. These plans should not be lightly varied. For this reason the schedules for the outward marches should be as easy as possible and each day an early start with all equipment on the move should be aimed at. This early start may be no sooner than eight o'clock if persistent morning mists are habitual and even this time may require cooks to be on their job at five. Ten miles on foot in a day in hill country with full equipment may be good progress.

An even division of the load among the carriers and constant checking is necessary, otherwise the workshy will be crossing the hills with impressively bulky but light loads, and this may cause resentment among the others.

The doctor will no doubt concern himself with such matters as spraying of sites to kill flies and mosquitoes and with routine matters of cleanliness in the preparation of food and the disposal of waste. He will have plenty of patients to attend to at each halt as the news of the arrival of a doctor will precede him. The treated patients and their friends will return to their villages and the free passage of the survey party will be the better assured.

It seems likely that having reached a central point in the potential storage basin, an assessment of the upper catchment area will be made, to see if this agrees physically with expectations based upon the map. Its general geology should be studied together with the value of any present-use occupation within the area to be flooded and its general value as a water storage basin. From this point, single-day expeditions may be pushed out to potential dam positions.

To cover the maximum ground in the shortest space of time, it seems likely that the return route will differ from the outer journey. As far as possible, the return route should coincide with the downward course of the river it is proposed to develop. In any event, this will lead to the plain and civilisation and the route can be planned accordingly.

Approaching mid-point of the possible period of stay, the further programme should be reviewed in the light of knowledge so far gained, to allow as much time as possible for the examination of the section of country between the provisionally selected dam-site and the possible site for the power station. By reason of the sharp fall in elevation this will almost certainly be rough country and probably entirely devoid of paths. In any instance, whatever paths there are will almost certainly follow the ridges so that

penetration to the route of the bed of the river will require a track to be cut through thick undergrowth all the way.

Assessment and Application of Data

On return to headquarters, separate reports on their individual interests will be prepared by all taking part and made available as soon as possible. These should contain every scrap of information that has been learned on any point whether it appears to be relevant or not. The reports will then be analysed and summarised in the form of recommendations. At this time it should be possible to formulate plans for the full-scale investigation of the area if, in fact, it has been decided to recommend this course.

An early preliminary requirement is to furnish improved means of access, first by pathways, successively improved to allow penetration by motor transport of increasing load-carrying capacity up to the final capacity needed for constructional purposes. Rain-gauging stations will be established and observers trained to keep records of rainfall and water flow. Action will be initiated to make a complete topographical and geological survey of the whole area involved. Plans will be prepared for assembling the labour forces to make roads and to investigate sites of major works and develop quarries. The necessary organisation to direct their activities and to maintain them in the field must also be established. Such major engineering work is necessary before a single constructional specification can be drafted and cannot be attempted before a favourable report has been agreed of the preliminary survey. It is for this reason that it is so necessary to spend time and money in conducting a carefully planned preliminary survey before arranging for the full-scale detailed survey.

British Steam Plant for Canadian Hydro System

The J. Clark Keith generating station at Windsor, Ontario, was opened on November 16. This power station is one of two new large thermal stations to be commissioned this year by the Hydro-Electric Power Commission of Ontario to supplement the power from the hydro-electric generating plants in the Province. The fundamental idea of installing steam-driven generating plants in the middle of a large water power system such as exists in south-west Ontario is not new. It has been discussed in a general way for at least 20 years, but one of the principal reasons why nothing was done was the proposed St. Lawrence water-way scheme, about which international agreement was needed between Canada and the United States before any effective work could be started.

During the war, however, rapid industrial expansion and development occurred in Toronto and indeed throughout the whole of south-west Ontario. As a result of this the Hydro-Electric Power Commission were faced with a power shortage which in some respects was more severe than the similar situation in Great Britain. Water-power development schemes were launched in 1945 and all resources that could be economically tapped were pressed into service. Some of these schemes are still unfinished. There is, however, an economical limit to the use of water power, particularly in northern Ontario and other areas of reserve water, due to the inaccessibility of the source of supply and the economics of high-voltage transmission over very long distances. These and other considerations turned the serious attention of the Hydro-Electric Power Commission of Ontario to the use of steam power situated near to the heavy-demand areas. One of these areas was Windsor, on the north bank of Clair River opposite Detroit.

Negotiations for the building of the Windsor station were commenced in 1947 and it was decided to install four 60,000 kW turbo sets together with boilers and condensing plant. Orders were placed for two units early in 1948 and two more have since been put in hand. When completed in 1953, Windsor will be the second largest steam-driven electric generating station in Canada, and its main purpose will be to back up the hydro-electric stations when water shortage reduces output or when power from the hydro stations is insufficient to meet peak demands.

The contracts for the steam turbines and electrical generators were placed with The English Electric Co. Ltd. and were built at the company's works in Rugby, England. The normal continuous maximum rating of each generating plant is 60,000 kW with a maximum economy rating of 48,000 kW, and a "capability rating" of 66,000 kW. Each of the four sets will run at 3,600 r.p.m. and the turbines are designed to operate with steam at 850 lb. per sq. in. and a temtemperature of 900°F.

The turbines are of two-cylinder impulse-reaction design, the high-pressure cylinder containing 18 impulse stages and the low-pressure double-flow cylinder one impulse and six reaction stages in each flow. Both high-pressure and low-pressure rotors are machined from solid forgings with the exception of one disc at each end of the low-pressure rotor carrying the last row of blades.

The blading is of stainless iron or chromium plated 5 per cent. manganese nickel steel, depending on the stress conditions. It is found that manganese nickel steel is particularly suitable for withstanding the heating necessary when attaching lacing wires by silver soldering, without air hardening and the consequent risk of the formation of hair-line cracks. All the moving blading is machined out of solid bar material and has integral roots.

The alternators are direct coupled to the steam turbines, the cooling medium being hydrogen in accordance with modern practice for high-speed turbo-alternators. The normal operating pressure inside the alternator casing is 0·5 lb. per sq. in., but the design is suitable for operation at a hydrogen gas pressure of 15 lb. per sq. in. The alternators supply current at 13,800 V, three-phase, 50 cycles, and are designed in accordance with the standard specification of the American Institutes of Mechanical and Electrical Engineers.

An outstanding feature of these alternators is the size and weight of the stator. The first, weighing 120 tons, was shipped to Canada early last summer. It was the heaviest single item ever to leave The English Electric Company's Stafford Works and one of the heaviest pieces of cargo ever to be shipped from the United Kingdom to Canada.

Terrain in 1948 showing excavation ready for dam and diversion dam

Los Peares Power Station

Some leading particulars are given of this important Spanish scheme and of the British equipment which is to be installed.

THE Los Peares hydro-electric station is owned by Fuerzas Electricas del Norveste, S.A., of Corunna, and is situated on the Mino, ten miles from Orense, in the north-west corner of Spain. It will be gathered from Fig. 13 that the power station is situated at the base of the dam and such is the nature of the site that the river bank has had to be excavated to accommodate it and an access road tunnelled through the hillside. This arrangement has been necessitated by the extremely large flow during the winter months, making it expedient to leave as large a spillway as possible.

The electrical arrangement of the station is on the unit principle, each generating unit being directly coupled to its own bank of transformers, without low-tension busbars, and the auxiliaries for each unit being supplied from the unit transformer. Provision is also made for interconnection to a station auxiliary board from which the general station auxiliaries are supplied. From the high-tension side of the main transformers the lines pass to a substation on the hillside above the dam. Here all switching is carried out at 132 kV. Under this arrangement each unit in operation is completely independent of all external supplies. There are three main sets.

All the electrical equipment in the power station and the substation, with the exception of one 4,000 kVA transformer, is being supplied by The British Thomson-Houston Co. Ltd., Rugby, and the water turbines are also included in their contract, having been sub-contracted to Boving & Co. Ltd., London.

We give below details of some of the plant installed.

Turbines

Each Francis turbine is rated at 72,800 b.h.p., 214 r.p.m., and is designed to give this output at a head of 93·32 metres, with a water quantity of 66 cu. m. per second at full load. The turbine will also operate, with a consequent reduction in output, at heads down to 67·73 m. at which head the output will be 53,000 h.p. Due to the large fluctuation in rainfall, the flow of the river varies very considerably between summer and winter, and during the winter there is ample water for the units to operate at full load. In summer the supply of water fails and output is maintained by lowering the head of the dam. To conserve the water supply as much as possible the turbines are designed to give their highest efficiency at their lowest operating head and at 53,800 h.p., thus conserving as far as possible the limited summer water supplies.

The butterfly valve, for isolating the turbine, is shown in section on the model (Fig. 12) and is being manufactured by Glenfield & Kennedy Limited of Kilmarnock. It will be operated by a servomotor which is supplied with pressure oil from the turbine governing system, and a bypass valve, motor operated, is provided to equalise the pressure across the valve before it is opened, this entire sequence being automatic.

Load and speed control are carried out by an

actuator, situated on the machine-room floor, through the medium of oil pressure and servomotors. The flyballs of the actuator are driven by an a.c. motor supplied by a permanent-magnet governor generator formed as an integral part of the alternator. Variations in speed are thus reflected in the flyballs which control the turbine speed by means of oil pressure operating on the turbine guide vanes through a servomotor.

The turbine itself, which has a fabricated steel spiral casing, has a total weight of 51 tons, the runner weighing 15 tons and the stay ring 36 tons.

Alternators

The alternators are each rated at 62,400 kVA, 53,000 kW, 11 kV, 50 cycles, 3 phase, 214 r.p.m. in accordance with B.S. 226 and are designed to incorporate a flywheel effect, for turbine governing, of 21 million lb. ft.^{2}. They are all designed to withstand the runaway speed of the turbine which is 400 r.p.m. The first machine is now being assembled for tests at the works.

The alternator is equipped with two guide bearings, one in the lower and one in the upper bracket, and a thrust bearing is formed as part of the upper bracket. This thrust bearing carries a total load of 400 tons including that of the rotor, the runner and the hydraulic thrust. All the bearings are of Michell segmental line pivoted-pad type and are arranged for drowned running, cooled oil being supplied from an external lubricating system. Several ingenious features are fitted to the bearings, for example, pressure oil seals to prevent oil leakage into the machine.

The stator is completely fabricated and is split into four sections to facilitate shipment. The winding is of the Roebel bar type, with the usual Haefley-tube insulation and a corona shield. The total weight of the stator is 100 tons.

The rotor is built up of a series of rims mounted on a spider which itself is mounted on a forged shaft. The rims, of which there are four to facilitate shipment, are built up of segmental punched plates each $\frac{1}{4}$ in. thick and are keyed to the spider. The poles are carried in dovetail slots on the outer face of the rim and are arranged with a strap to prevent the coil sides bulging, instead of the conventional vee-block. This arrangement is such that the poles may be removed without disturbing the rotor. The pole itself is arranged with air ducts to facilitate rotor cooling and the winding of the field coil is fabricated from copper strip, the joints being of the interlocking jigsaw type. The total weight of the rotor is 250 tons.

The main and pilot exciters, and the governor alternator for supplying power to the governor motor, are all mounted on top of the alternator and are cooled naturally.

Other features are the brakes and jacks which are mounted on the bottom bracket and operating on a braking ring on the lower half of the alternator rotor. The alternator itself has a closed system of ventilation and is cooled by means of four air-water heat exchangers, shown in the corners of the machine pit (Fig. 12). These coolers are so arranged that any one may be withdrawn for servicing while the machines continue on load, although at a slightly reduced output.

Transformers

The main step-up transformers, which are arranged on the platform above the station, are each rated to

Fig. 1. View of the diversion dam in 1950

Fig. 2. The dam viewed from downstream in 1950

give a bank output of 61,400 kVA at 50 cycles, 3 phase, the no-load bank ratio being 11/132 kV. In order to reduce the size and weight as much as possible, largely in view of the difficult access to the station, three single-phase transformers are used per bank and each transformer is B.S. "OFW" rated, that is, with forced oil circulation and water cooling. Duplicate oil coolers, each of full capacity, are provided.

As these are full-capacity coolers, either cooler may be withdrawn for servicing with the bank continuing on full load. The oil circulation is by means of the B.T.H. oil-immersed pumps wherein both the motor and the pump are completely immersed in oil and there are, therefore, no stuffing boxes through which the oil may leak. In addition the oil pressure is maintained greater than the water pressure, thus ensuring that any leakage in the coolers takes place into the water and not into the transformer oil.

Each transformer is mounted in a fabricated tank and the winding is of the continuous disc type, with electrostatic shields and graded insulation on the 132 kV side, where the system neutral is earthed. The transformers are each fitted with off-circuit tapping switches on the H.V. side to give a voltage range of 145·5/138·578/101·815 kV.

The L.V. connections for the transformers are made on the outside of the banks, as may be seen in the model, and are carried through insulators into the 11 kV isolators, which are immediately below the transformer platform.

In the auxiliary transformer room, which may be seen directly below the control room, there are three unit transformers each rated at 1,000 kVA, and, in addition, there are two 750 kVA transformers. The former, which have a voltage ratio of 11/380 V with off-load taps for $\pm$ 2½ and 5 per cent., are those associated with the three alternators, and the two 750 kVA transformers which have a voltage ratio of 20,000/380 V with off-circuit taps for $\pm$ 5 per cent., are connected to a local 20 kV supply to give a standby supply when the station is completely shut down. The 1,000 kVA transformers are connected to the unit board applying to the respective turbo-alternator groups and interconnected with the station auxiliary board. The 750 kVA transformers are connected directly to the station auxiliary board, and, in the event of the station being completely shut down, the unit boards may be connected to a live supply by the interconnectors.

Fig. 4. A view of the dam from above showing the power-station excavation

Fig. 3. The dam viewed from downstream in 1951

Control Room

Miniature-type control boards are used in view of the large number of circuits to be controlled, since this type of board enables all essential controls to be grouped in a relatively small space, under the complete supervision of one attendant. All relays and similar apparatus are dissociated from the control board and are mounted elsewhere as mentioned below. The board controls the following circuits:—

Centre control board—
132 kV.
3—Alternator-transformer units (11 and 132 kV sides).
5—Outgoing feeders
3—Local transformer units.
1—Bus coupler.

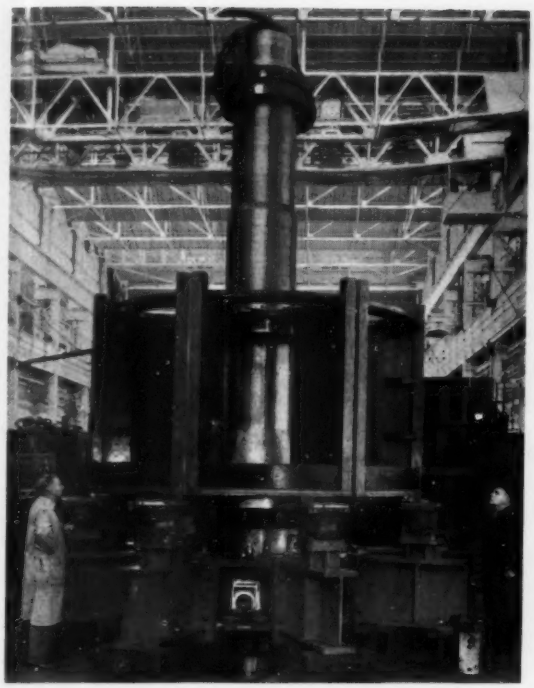


Fig. 5. Alternator-rotor spider and shaft mounted on bottom bracket

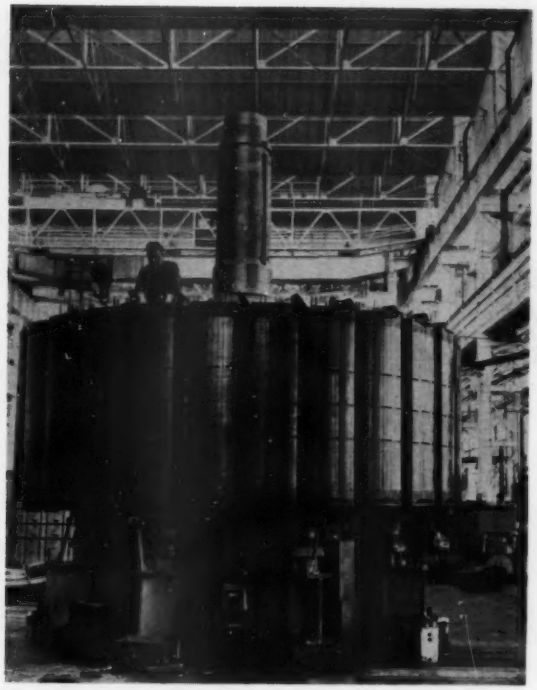


Fig. 6. Complete alternator rotor and bottom bracket in the B.T.H. works

Left-hand control board—20 kV
2—Feeders.
2—Incoming transformer supplies.
1—Station transformer supply.
1—Bus coupler.

Right-hand control board—380 V.
3—Incoming supplies from 1,000 kVA transformers.
3—Incoming supplies from 750 kVA transformers.
1—Diesel alternator set.
General station interconnections.

On these panels there is also control and indication of the spillways and spillway gates, together with indication of head-water and tail - water levels. Station metering and other similar facilities are also incorporated on the board.

Around the walls of the room are arranged the relay panels associated with the alternator and the voltage regulator. All other relay panels for all the outgoing feeders, 132 kV and 20 kV and similar supplies, are arranged in the plant house at the switching site, and interconnected with this control room by multicore cables.

Also in the corner of the room are the controls for the battery and for the supplies from the battery of the station, including mercury-arc rectifier set and trickle and bulk-charging equipment for the 220 V, 220 ampere-hour battery and a 24 V battery for illuminating the board.

The essential controls for picking up and adjustment of load, etc., are arranged on the control desk in the centre of the room.

In view of the fact that the relays are disso-

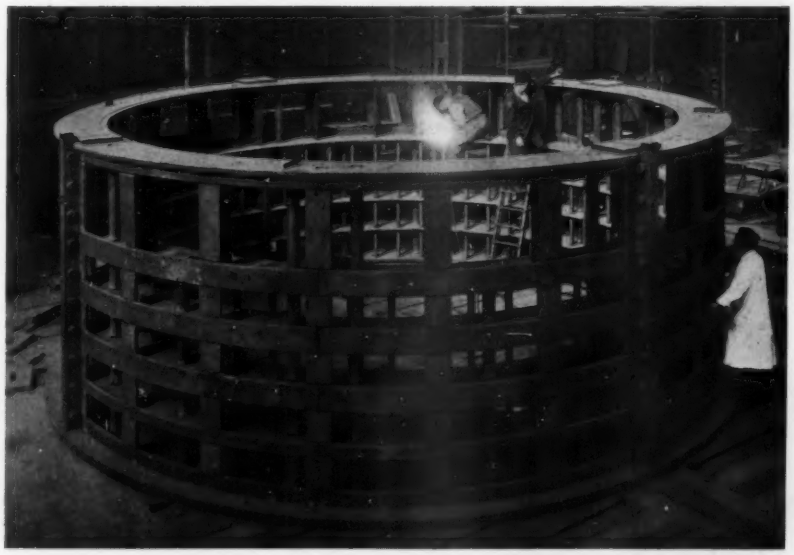


Fig. 7. Stator frame in course of erection

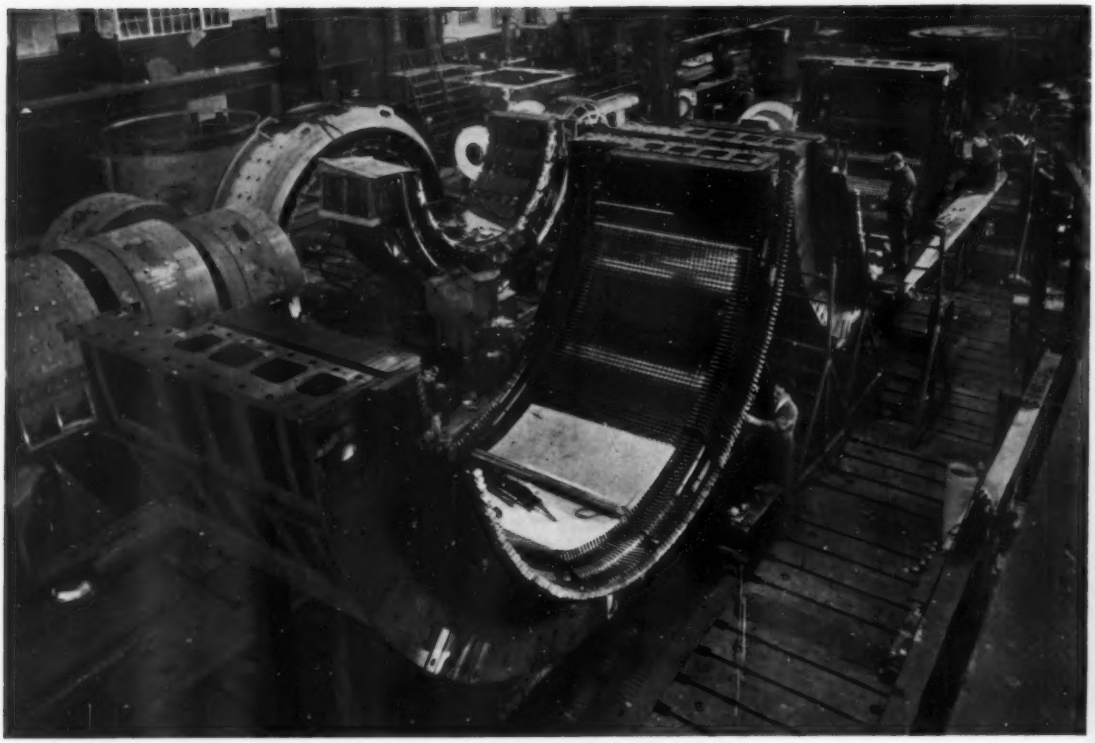


Fig. 8. The halves of the stator in course of winding

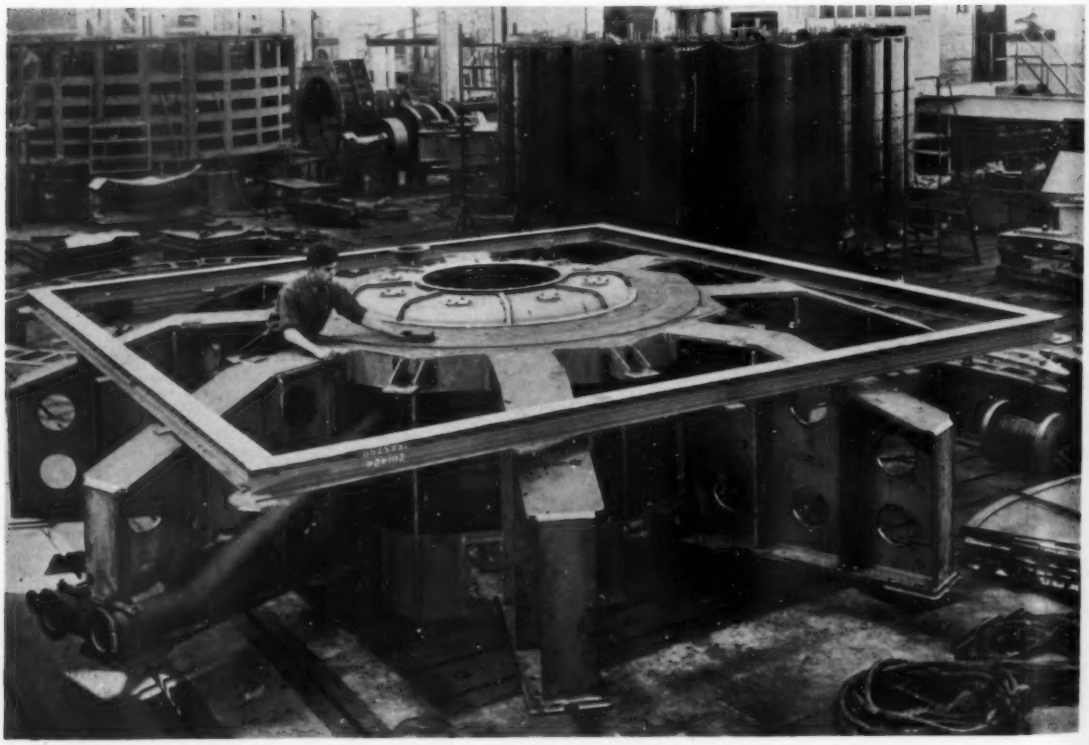


Fig. 9. Top bracket and side arms. The rotor and stator are seen in the background

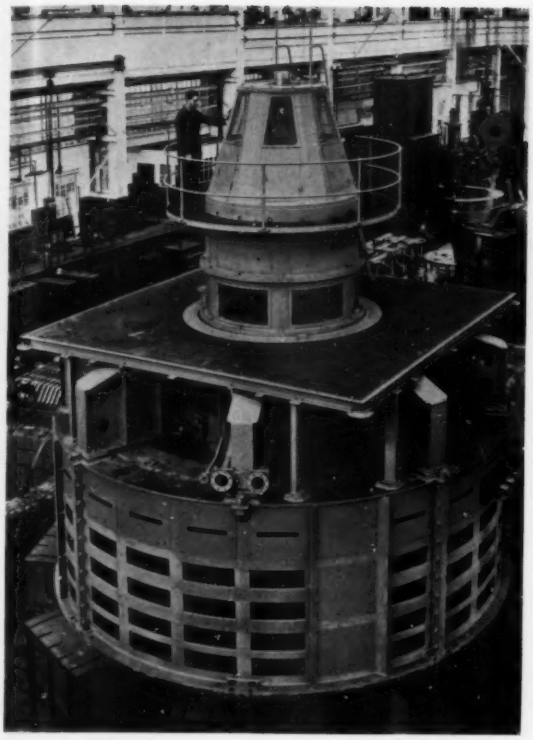


Fig. 10. The completed alternator for one of the sets in the B.T.H. works

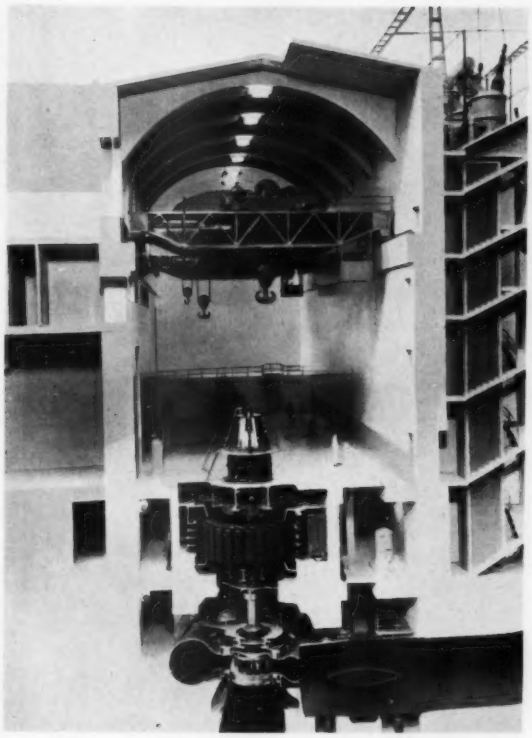


Fig. 12. Another view of the scale model showing one of the generating sets

ciated from the control board, it is necessary to have a complete alarm scheme, and this is provided by means of S.T.C. illuminated alarm annunciators mounted at the top of each control panel.

All incoming cables from the power station itself and from the substation are marshalled in a cable room immediately below the control room.

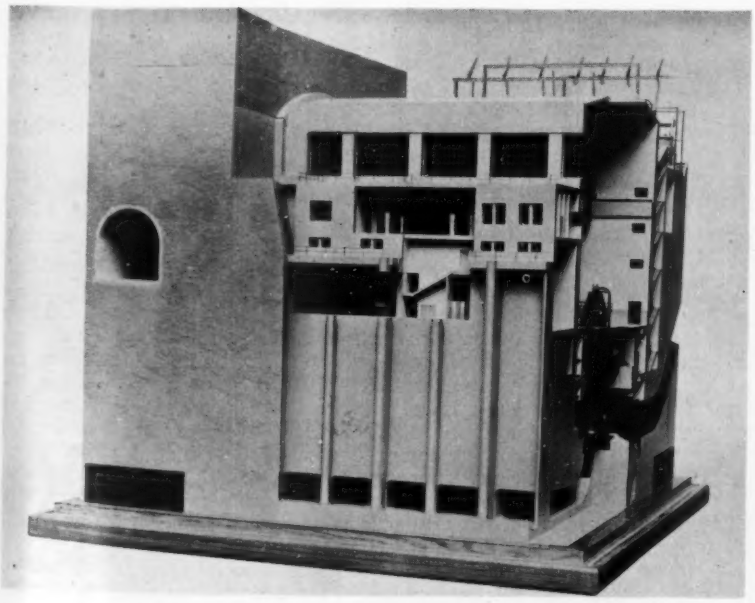


Fig. 11. The scale model of the Los Peares power station

General Details

As previously mentioned, each unit is independent in operation, and on the machine floor adjacent to the unit are the turbine gauge panels, the unit auxiliary board and the actuator. From these three, the machine may be started up and run up to speed ready for synchronising. The essential controls and alarms for the machine itself are centred on the turbine gauge panel, where there is also a mimic diagram of the hydraulic side of the machine.

The station auxiliary board is cut off by the section, but both this and the auxiliary unit board are built up of AG and AJ switchgear.

In an emergency, should no outside supplies be available, a 180 b.h.p. diesel alternator standby set is also provided. This is a Mirrlees-B.T.H. unit of the standard type for this drive. This set is interconnected with the station auxiliary board and is arranged for remote control

Fig. 13. An artist's impression of the Los Peares dam and power station

from the control room.

At the request of the customer, Mulsifyre fire-fighting protection is provided over the main step-up transformers, the auxiliary transformer room and the diesel room. Protection is also extended over the Mulsifyre equipment itself. This equipment is arranged on the floor immediately below the transformer platform and is visible in the model. The supply of water to this unit, and to all station auxiliaries, is provided from a tank arranged on the side of the dam.

Switching Site

As will be gathered from the details given under the heading "Control Room" there are five outgoing feeders at 132 kV, and each of these feeders will have an OW type circuit breaker with single-phase auto-reclosure. The remaining six circuits, that is, three alternator circuits, two local transformer circuits and one bus coupler, will be of the standard type OW circuit breaker.

The 20 kV circuits will each be JB tanks of the conventional type.

Also to be supplied by the B.T.H. Company for this site is a 6,000 kVA, 132/20 kV transformer with on-load taps on the L.V. side for $\pm$ 10 per cent. in 11 steps. This will run in parallel with the existing 4,000 kVA transformer mentioned above.

Also in the relay and plant house on the site will be all the relay boards associated with the equipment in the switching site, together with air compressors, since all circuit breakers will be compressed-air operated, oil-handling plant and the usual equipment associated with a switching substation.

The B.T.H. Company have also received the order from the same customer, forming part of the same contract, for the supply of switchgear and transformers for two additional substations at 132 and 66 kV in the customer's system.

Switchgear for Beauly. Cooke & Ferguson Limited, Openshaw, Manchester, have published a profusely illustrated pamphlet describing the 33 kV outdoor switchgear which they have supplied through Messrs. Kennedy & Donkin for the Beauly substation of the North of Scotland Hydro-Electric Board. This installation is an eight-circuit 500 MVA assembly comprising two 132/33 kV 15 MVA incoming transformer circuits equipped with 400 A isolating switches, oil circuit breakers, and voltage and earthing transformers, five outgoing circuits each equipped with 400 A busbar isolating switch, feeder isolating switch and voltage transformer, and one spare circuit equipped with 600 A busbar isolating switch and oil circuit breaker. Two 800 A bus-section isolating switches are included.

The Critical Intermittent Impact Factor in Wind-Turbine Design

In this article PERCY H. THOMAS of Washington, D.C. explains the function of impact in the performance of wind turbines, and shows how a proper appreciation of this factor can lead to much more efficient designs

THIS article follows the definitely timely suggestion of the editor of *Water Power*, that engineers would welcome a descriptive technical statement of the vital part played by the little-understood impact factor in wind-turbine design. On account of the almost complete absence in the literature of any adequate treatment of turbine aerodynamics, power engineers have scant knowledge of the subject, in spite of its far-reaching potential advantage to the power industry, notably in coal-scarce countries.

A simple picture of the action of the wind turbine will now be drawn, for the purpose of making clear the new approach that opens the way to obtaining the optimum output of energy from the wind—specifically, the extraction from a given-sized wheel of an amount of power greatly increased as compared with any so far actually attained, even from the well-known Smith-Putnam wind turbine installed on Grandpa's Knob, a mountain in the state of Vermont, U.S.A.

The optimum-power wind turbine carries two, three or four narrow spokes (blades) on a hub, the width of the blades at the tip occupying only a few per cent. of the whole circumference, with the blades moving at a very high speed, a maximum, of course, at the tip. The wheel faces the wind stream, which for the purpose of this analysis is assumed to be made up of a multitude of filaments (streams) of moving air, each filament following its own path, and supplying its own inertia and momentum. These filaments are not confined within walls, like water in a penstock, but still any one filament acts, to a very considerable degree, as though it were confined, due to the inertia of the surrounding air filaments. However, this confinement is only momentary, and arises against impact forces of extraordinary abruptness, such as an impact caused by the sudden appearance of one of the fast-moving blades of the wheel across the course of a filament. If the impact be sufficiently abrupt, the momentum of the air filament will then impress its force on the blade, since it is restrained at the sides.

The numerical magnitude of this force on the blades is found to be proportional to the square of the abruptness of the impact, that is, to the square of the blade velocity. The effectiveness of the abruptness of the impact as a completely dominating factor may be experienced by vigorously slapping a surface of water with the hand, in which case a stinging resistance is met. If now the water be struck with ten times the speed the momentary resistance of the water would be increased one hundredfold, and would approach the firmness of rock—for the instant. With the linear tip speeds of the aircraft propeller exceeding 1,000 ft. per sec., and that of the turbine roughly half, the pressures may reach astonishing values, said to be 1,000 lb. per sq. ft. in propellers.

Returning to the filament of air across whose path the blade has cut, it is clear that after the impact the momentary force will drop away very rapidly as the air in the filament is slowed down. However, as the impact of the filament builds up, the lateral pressure on the surrounding filaments mounts and a lateral movement starts under this back pressure. This lateral movement in the surrounding filaments grows as the momentary impact persists, and moves the fastest at end of the impact even as it dies down, as is characteristic of acceleration. This action is exceedingly important for it is this temporary lateral motion that in the end limits the beneficial action of increasing the impact. While this pressing back of the surrounding filaments is spoken of as "lateral" to distinguish it, the lateral movement thrusts the nearest filaments into the path of others, thus impeding their progress and adding to the impact pressure on the blade.

On the other hand the blade, continuously cutting fresh filaments of air as it does in its revolution, is impressed with a perfectly constant impact force. This action forms the basis for a favourable extraction of energy from the wind.

Laboratory research has shown that there are three dominating factors governing the maximum output from a turbine. These are, the ratio of the wind velocity to the blade speed (the impact), the solidity ratio (the portion of the wheel circumference covered by the total blade width), and the angle of attack. In connection with this velocity ratio it should be noted that the higher the velocity of the main wind stream the more quickly will the stagnated air be swept away. The important factor is thus the ratio of velocities. The angle of attack is also a factor in determining the degree of stagnation of the filament velocity, which may be even left negative by the blade.

The physical effect of the blade passage, as stated, is the stagnation of the filaments of air directly involved, followed by the sweeping away of the stagnated air. If the blade speed be increased beyond the optimum value (or if the space between blades be decreased), the wind velocity, just stagnated, will not be fully restored when the next blade arrives, reducing the available supply of energy. If the blade speed be reduced, on the other hand (or the space be too great) as in the Smith-Putnam turbine, the wind will blow through the open space without full contribution of energy as soon as the filament velocity has been restored.

The question naturally arises, what are the measurable limitations to the advantage to be obtained from high blade velocity. One limitation in large-capacity wheels is centrifugal force in the blades. This is a real limitation, forcing the use of light metals. Another limitation is the prohibitive resistance to the blade

from the air at speeds beyond the speed of sound. These limits to blade speed are easily handled by the designer. There remains the difficulty of getting definite data to determine the limiting effect of the bypassing of air around the wheel with excessive values of blade speed, which is very complex. When the optimum value of the blade speed is exceeded the effect is to force some of the air filaments out of the range of effectiveness on the wheel.

It should be pointed out that the body of air affected by the back pressure from the impact on the blade is not cylindrical in shape, as it would be if based on the wind wheel circle, but is shaped like a lop-sided wedge based on the shape of the blade. The penetration of the stagnating effect is greater behind the tip of the blade since the velocity there is greater. This peculiar-shaped wedge of "back-pressure" air revolves around the wheel circle, following each blade. This would present a very complex and confusing picture to the eye, were back-pressure visible.

In addition to the pressure caused in front of the revolving blades, as already explained at length, as is well known there is produced a similar impact suction downstream from the blades, the effect being much the same in nature and adding to the total pressure on the wheel. Practically all laboratory tests on blades and wheels in wind tunnels, measure the integrated effect of the pressure and the suction.

The full appreciation of the nature of this impact action, effecting bodies of air not passing through the wheel circle, as already stated, has led to a material increase in the energy obtainable from the air in motion. While apparently investigators have had only a very imperfect conception of the clear-cut impact action, they have been quite conscious of the fact that back-pressure from the wheel had an important effect in limiting the output of wheels. There seems to have been little realization by wind-turbine engineers of the part played by the impact *per se*.

Considering the absence of walls for the air filaments, and the impracticability of measuring the local, momentary variations of pressure in velocity in the wind stream, it is hopeless to expect that a theoretical mathematical expression could be derived to indicate the net result on wheel efficiency. However, to get some approximation from which could be derived a formula for covering the net effect of impact taken with the two other critical factors, it was proposed many years ago to replace the wheel with an imaginary element having certain hypothetical properties (actuator disc) which were so chosen as to support a formula in mathematical terms. Such mathematical expressions have been introduced into many formulae relating to wind-wheel performance, especially for aircraft propellers. The difficulty appears that this simplifying assumption so introduced into formulae is based on the implicit assumption that the air flow through the air wheel is of uniform velocity over the whole wheel circle and is also constant with time. Obviously, no such condition is admissible with impact-type wheels. It so happens that the error introduced when the assumption is used may or may not be important according to conditions. However, in the case of the wind turbine the error to be expected is far more important than in any case of propellers. It may be pointed out that in wind wheels in which the *whole surface* of the wheel is covered with blades, the actuator-disc assumption may be useful.

This conclusion seems to leave the designer where he was before, without a guide to choose his proportions. Fortunately, a group of researchers in England* took the bull by the horns, and through a long series of experiments derived a group of curves by which the net effect of any usual combination of the three critical factors already referred to on the wheel performance could be determined. This very valuable series of researches will repay study.

Most writers on aerodynamic subjects do not seem to have been aware of these British researches. When properly used, the designer may proceed with his work basing his information as to the effect of any combination of the three critical factors that he may wish to explore on the curves of these British researches.

To warn a designer against the temptation to adopt without investigation ratios of wind velocity (represented by plane speed) to blade speed found satisfactory in propellers (ratios of 1 to 3-5), it will be pointed out that this ratio is limited in propeller use by considerations having nothing to do with the inherent effect of the ratio on efficiency *per se*. The maximum blade speed is limited by the speed of sound, as already explained, and the equivalent of wind velocity in the turbine, that is the plane speed, is determined by the service of the plane. On the other hand, with the turbine, while there is the same limitation on the blade speed (even more limiting than in the propeller), the values of wind velocity for which turbines are designed are far less than the plane speeds. This permits any ratio found most advantageous by the designer. The writer has used values from 1 to 10 to 1 to 13. These higher ratios will be found to offer very much higher efficiencies.

If it be permitted to point a moral in the Victorian sense, it may be stated that any optimum wind-turbine design arrived at without properly co-ordinating the three critical aerodynamic factors, of which the intermittent impact is the chief, will be purely accidental.

To those who wish to follow this subject further, and to turbine designers seeking a mathematical treatment, reference is suggested to the writer's monograph, "Aeronautics of the Wind Turbine," issued by the Federal Power Commission, Washington, D.C., U.S.A., 1949.

Fraser River Model. According to the Quarterly Review of the National Research Council of Canada, a movable-bed hydraulic model of the Fraser River estuary from New Westminster to the sea has been constructed to a horizontal scale of 1 : 600 and a vertical scale of 1 : 70 on the campus of the University of British Columbia. The area under study is tidal, and to facilitate control of tides a section of the Gulf of Georgia and the river channel to the limit of the tidal influence have been included. Automatic controls which will vary the discharge of the river and control the height of the tides in accordance with prototype data over a one-year period have been incorporated. The river, which has two channels and is navigable to ocean shipping as far as New Westminster, carries a large silt load, and the effects of large-scale dredging are to be studied.

* Great Britain Ministry of Supply, Royal Aircraft Establishment Advisory Committee for Aeronautics. Reports and Memoranda 639 Multiplane Interference Applied to Airscrew Theory.

Abstracts from the World Technical Press

Co-ordination of Insulation

The co-ordination of the insulation in high-voltage systems has now reached a stage where a definite table of values for the test voltages can be drawn up. A considerable amount of research has been carried out on voltage surges which may either originate in the system itself or may be induced by thunderstorms. Three types of surges have to be considered. The first is caused by changes in the constants of the system and follows all the more rapid transients caused by switching operations. If the neutral is solidly earthed, the ratio of surge voltage to service voltage can be as low as 1·2 for fairly short lines and thermal power stations, and rises up to a maximum of 1·7 for long lines without interconnections or in the case of hydro-electric stations. The duration of these surges is of the order of several tenths of seconds with the usual protective gear. A second type of internal disturbance are the switching surges themselves, consisting usually of oscillations at the natural frequency of the system. The voltage ratio in this case lies between 1·5 and 3, but values up to 5 have been measured in France for some particularly onerous duties such as disconnecting a transformer which itself is not solidly earthed, from a grid with earthed neutral. Travelling waves caused by lightning are aperiodic and are usually represented by a 1-50 surge although there is little experimental information confirming such a steep wave front. The maximum voltage normally exceeds the flash-over voltage at some point of the system, leading to a chopped wave form.

In modern testing technique, high-voltage equipment is subjected to three tests: measurement of the ionisation losses at the maximum service voltage; a 50 c/s test lasting for one minute which corresponds to the low-frequency internal surges; and an impulse test to ensure that it will withstand travelling waves. The latest values adopted are as follows (all values in kV):

Maximum permanent	Test voltage at 50 c/s for 1 min.		Full-wave impulse voltage	
	n = 100%	n = 80%	n = 100%	n = 80%
3·5	16		45	
7	22		60	
11·5	28	No values	80	No values
17·5	38		100	
23	48		125	
37	70	Not	180	Not
50	95	yet	235	yet
72	140	decided	325	decided
100	180	150	450	350
123	220	180	550	450
145	260	220	650	550
170	305	260	750	650
246	442	380	1050	900
300				1050

The reduced voltages for n = 80 per cent. refer to a system whose neutral is solidly earthed so that an

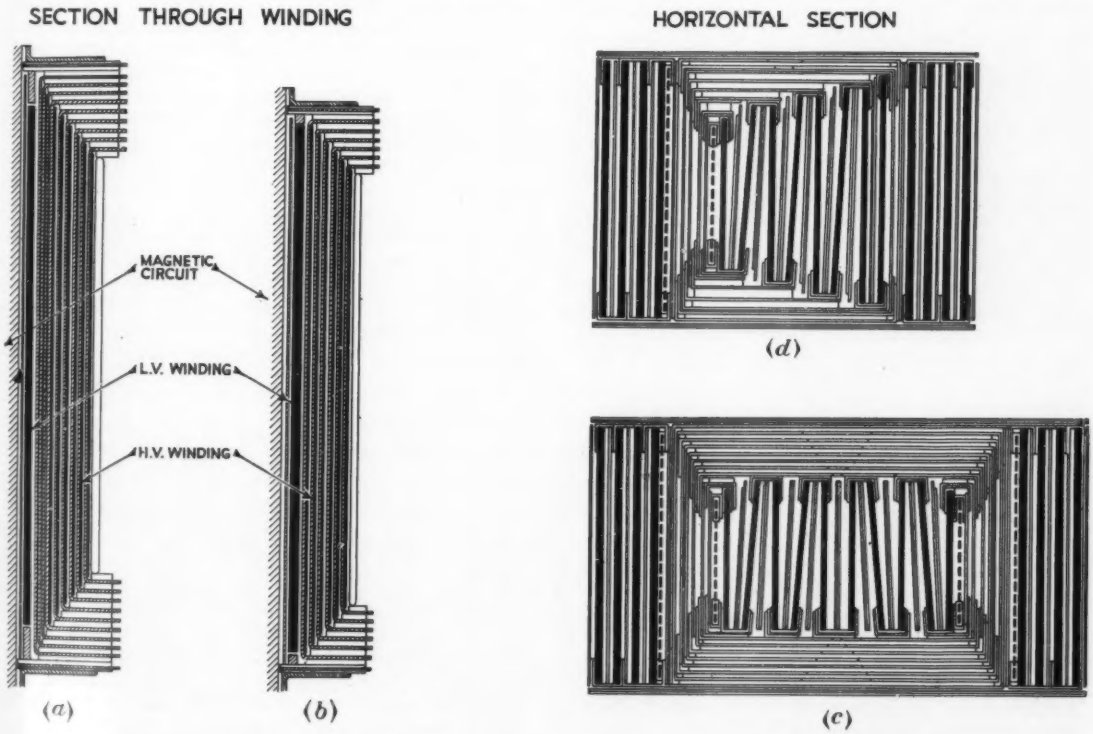


Fig. 1. Single-phase 25 MVA 225/10 kV transformer with full and graded insulation.

(a) and (c): Insulation levels 442 kV line and neutral, impulse test (1-50): 1050 kV.
(b) and (d): Insulation levels 442 kV line, 150 kV neutral, impulse test (1-50): 900 kV.

earth fault on one phase produces no more than 80 per cent. of the line voltage across each of the other two phases.

The first test aims at ensuring that the insulation will withstand the service voltage during its useful life, say 25 years. Although a certain margin of safety may be specified, no information can be obtained on localised ionisation with the usual equipment. Tests are being conducted at present to develop a technique using a cathode-ray oscillograph which promises to allow even small defects to be noticed and located. Considerable research is still required, however, until it will be possible to determine from tests the useful life remaining in a transformer which has already been in service for some time. The 50 c/s test is usually taken at approximately 1·75 times the line voltage; this corresponds to a factor of safety of 2 on voltage surges arising within the system itself and having an average value of 1·5 times the phase voltage. These values, as well as the one minute duration, are based mainly on existing practice in the absence of more conclusive evidence. The main problem is how to detect any breakdowns during such tests other than visually or by ear; active research on this aspect is in progress at present.

The impulse level of the system depends on the surge diverters installed as they must not operate on the slow internal surges of the system. A margin of 10 per cent. on this voltage, together with a ratio of 3·5 of flash-over to extinction voltage, leads to an impulse test at 3·5 × line voltage if a 20 per cent. safety margin is provided. Higher values are required if the system is not solidly earthed (n = 100 per cent.). The question of testing transformers with chopped waves is still very much under discussion. In order to make comparative records at low and full voltage, as is usual for full-wave tests, it is essential to control accurately the instant at which the wave is chopped off. The recording of such impulses becomes very difficult at voltages exceeding 500 kV since no accurate voltage dividers for these frequencies are available. There is very little information on the steepness of the back of a chopped wave; while at lower voltages the natural frequency is the governing factor, high-voltage surges are controlled by the characteristics of the arc, and the rate of change of voltage is lower. The danger of the chopped wave lies in the fact that both front and back may induce voltages in the first turns of a winding which may be superimposed if the time interval is sufficiently short; the total effect depends on the natural frequency of the transformer and while it is not serious for small units, it may be important for larger ones and may also differ with the type of construction.

The effect of switching surges may be covered either by low-frequency or by impulse tests. In the first case, a voltage of 1·7 × line voltage would be required; this case is thus covered by the normal 50 c/s test. Systematic tests by Bellaschi have shown that switching surges may be simulated by an impulse test exceeding their peak voltage by 10 per cent. This leads to 2·7 times the line voltage; compared with a value of 3·5 during the actual impulse test, there thus remains a safety margin of 30 per cent. to cover atmospheric pollution, rain, etc. The normal test values appear therefore to be sufficient to cover also the case of switching surges. A comparison between the two insulation levels, depending on the earthing of the neutral, has shown that the lower one involves only 80 per cent. of the cost of a fully insulated transformer. Since surge diverters are included, there is no lowering of the safety level, but the grading of the insulation from phase to neutral leads to a very appreciable reduction in size (see Fig. 1). (*M. R. Langlois-Berthelot, Bull. Soc. Française des Électriciens*, Vol. 1, No. 8, August 1951, p. 419, 22 pp., 9 ff.)

Optimum Utilisation of Seasonal Reservoirs

This survey deals with the study of a problem of theoretical economy in the utilisation of seasonal storage reservoirs operating in conjunction with a system of thermal plants, and aims at reaching an economical optimum in the working of French seasonal storage considered as a whole; it proceeds from two simplifying hypotheses:—

(i) the consumption curve determined for one year is covered by a fixed amount of thermal power production, and by an unpredictable amount of hydraulic power production following the law of probability of the inflow;

(ii) only two factors dependent on operating policy are taken into account: waste of water resulting from overflow, and inadequate water storage.

The author is thus in a position to define two different operating policies: economy of coal consumption in a system provided with superabundant equipment, and a "safety first" policy in a system in which the equipment presents risks of deficiencies. The solution of the problem lies therefore in a compromise between these two aims of economy and safety. The theoretical considerations are derived from Massé's principle of " marginal expectancies."

It is obvious that assumptions as to costs of thermal production on the one hand, and insufficient water storage on the other, cannot be avoided; the author has therefore devised a "danger point" corresponding to a definite time of the year. Above this point the operation of the reservoir can be said to be within the safety margin, whereas below it, operation is carried

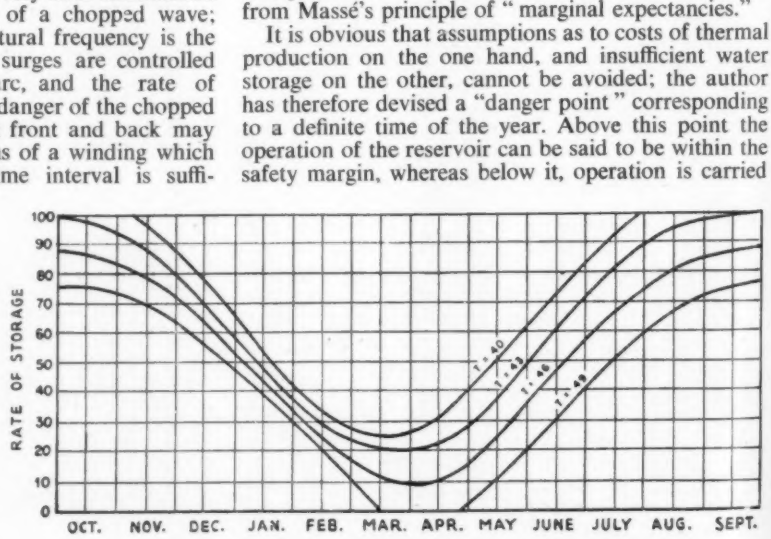


Fig. 1. Danger curves as a function of thermal possibilities.

Equipment as per Monnet plan: H = 88.5 per cent. of reduced consumption.
Rate of reserves: = 10.7 per cent. of hydraulic production capacity.
T = thermal possibilities in per cent. of reduced consumption.

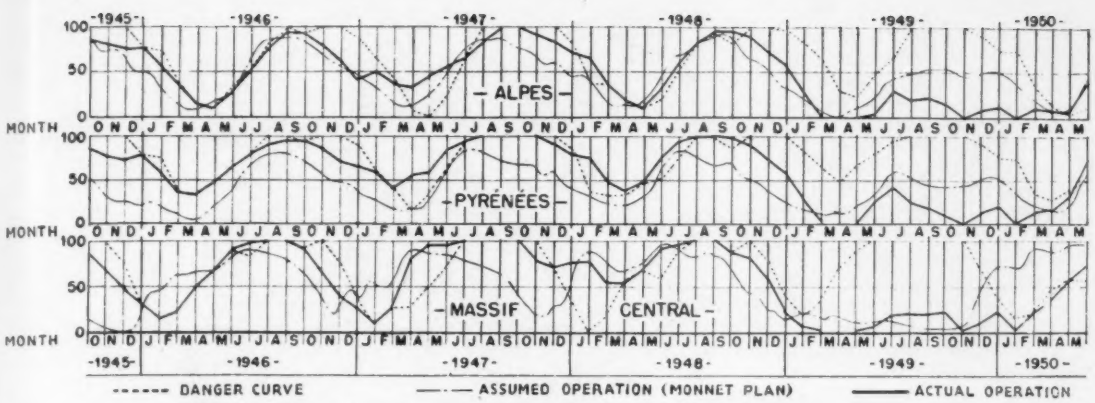

-1945-
-1946-
-1947-
-1948-
-1949-
-1950-
100
50
0
MONTH
O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M
- ALPES -
- PYRÉNÉES -
- MASSIF CENTRAL -
DANGER CURVE
ASSUMED OPERATION (MONNET PLAN)
ACTUAL OPERATION

Fig. 2. Comparison between assumed and actual operating curves

out on the basis of coal economy; by shifting the time of the year a "danger curve" is substituted for the "danger point." These theoretical considerations are followed by suggestions for the plotting of these danger curves (Fig. 1), and for practical applications.

The author does not claim that his method is to be accepted unreservedly; the graphs in Fig. 2 show, for example, that a mode of operation based on these danger curves does not necessarily mean that the seasonal reservoirs instanced will operate in full agreement with these curves. (In addition to the danger curves and to the curves of actual operation, these graphs also show the assumed trend of operation in connection with the equipment provided by the Monnet plan.) He feels confident, however, that his system of danger curves will permit carrying on with closer approximation the investigations previously made on the problem of determining the extent of the equipment which will ensure an optimum utilisation of seasonal storage reservoirs. (G. Morlat, Hydraulic Research Engineer, Electricité de France, *La Houille Blanche*, Vol. 6. No. 4, July-August 1951, p. 497, 14 pp., 6 ff.)

Pipe Burst at Waldshut Power Plant

In the course of reception tests carried out at the Waldshut power plant of the Schluchsee Development (see WATER POWER, October 1951, p. 398) a burst occurred at a pressure of 18 at. in the 1·6 m. diameter pipeline feeding the turbine of the fourth generating set. Of the four 44,000 kVA sets, two were already in operation, and the two remaining sets had still to undergo their reception tests. The mishap occurred in the evening of October 16, 1951, while switching-off tests were in progress on No. 3 set, and did not affect this set but No. 4 set which had not yet been put into service. As usual in such tests, the testing pressure exceeded the normal working pressure.

The water released by the burst rose from the pipe with such violence that a 50 cm. thick concrete ceiling was ripped up and the south front of the building destroyed; in a matter of minutes the whole of the power house was under water. Two fitters at work at the time in the turbine pits are missing.

According to an official statement made in the Baden Diet, the accident was probably caused by some deficiency in material or design. *(Technische Rundschau*, No. 43, 26.10.51, pp. 28/29, 5 ff.)

The Mauvoisin Scheme

This large-scale project is based on the utilisation, in two stages, on an aggregate head of 1,480 m. of the waters of the Dranse de Bagnes between Mauvoisin, upstream of Fionnay, in the uppermost section of the Bagnes valley (1,950 m. above sea level), and Riddes in the plain of the Rhône (470 m. above sea level).

Owing to an extensive catchment area comprising many glaciers, it will be possible to fill without pumping the storage lake which is sited in an uninhabited and unproductive region of the Pennine Alps. Once it has been completed the Mauvoisin arched gravity dam will have a height of 180 m. above the bottom of the valley, and ensure a storage of 157 M cu. m. of water. In an average hydrological year the two power plants to be erected at Fionnay and Riddes (see Fig. 1) will produce 756 M kWh (531 M in the winter and 225 M in the summer period) and thus contribute to a substantial extent to the supply of electrical energy in Switzerland.

Work started in January 1951 on the main sections of this project which presents the following characteristics:—

		Covered by glaciers
Natural catchment area	113·5 km²	45%
Additional catchment area:—		
Left bank (Séry, Corbassière and Bocheresse torrents) ...	40·2 km²	59%
Right bank (Louvie, Severeu and le Crêt torrents)	17·3 km²	7%
Total catchment area	171·0 km²	44%

Useful storage capacity of lake: 157 M cu. m.

Dam:—

Type: gravity arch.
Height: 227 m. above foundation, about 180 m. above bottom of valley.
Volume of concrete required, about 2 M cu. m.

Fionnay Power Plant:—

Water intake, about 90 m. upstream of dam.
Pressure tunnel on left bank, 4,720 m. long, 2·9 m. diam.
Surge tanks with top expansion chambers.
Pressure shaft 460 m. long, 2·40 m. diameter.

Underground power house excavated in rock upstream of Fionnay, equipped at the outset with two and, once completed, with three generating sets driven each by a vertical-axle Francis turbine.

Gross head: 459-309 m.

Installed inflow to turbines, 23 cu. m. per sec. (two units).

Maximum capacity: 85,000 kW (two units).

Riddes Power Plant:—

Water intake direct from River Dranse, with compensating reservoir at Fionnay.

Pressure tunnel on right bank 14,620 m. long, 3·25 diameter.

Surge tank with bottom and top expansion chambers.

Single, later double, penstock 1,854 m. long, 1·70/1·5 m. diameter.

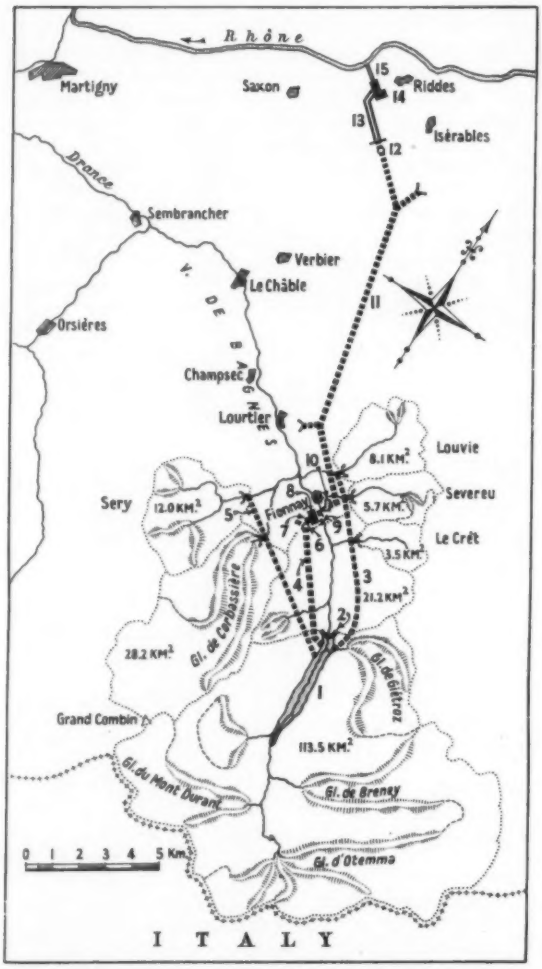


Fig. 1. General layout of Mauvoisin hydro-electric scheme.

1 Storage lake.
2 Mauvoisin Dam.
3 Collecting tunnel.
4 Intake tunnel to Fionnay power house.
5 Collecting tunnel.
6 Surge tank.
7 Steel-lined shaft.
8 Fionnay power house.
9 River intake.
10 Compensating reservoir.
11 Intake tunnel to Riddes power house.
12 Surge tanks.
13 Penstocks.
14 Riddes power house.
15 Tailrace.

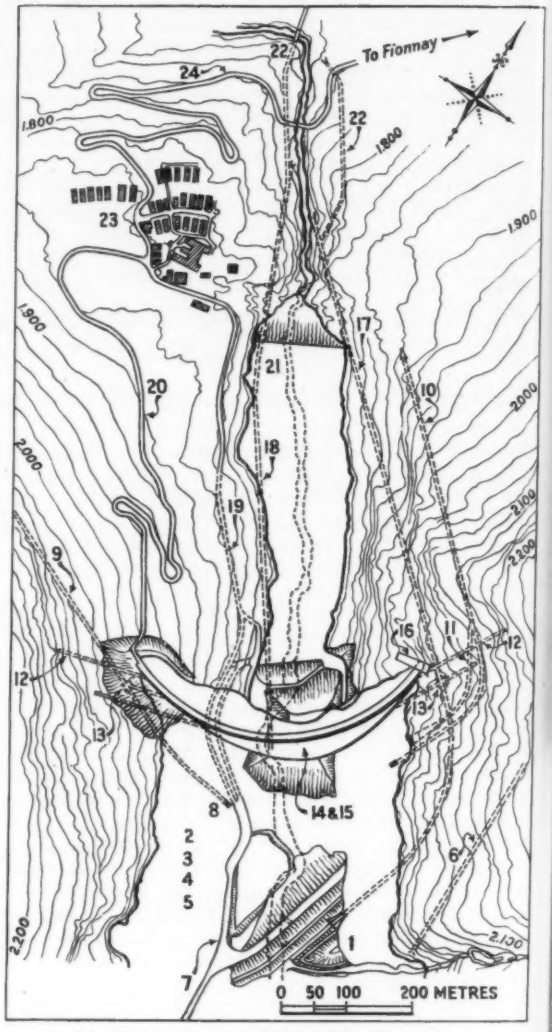


Fig. 2. Layout of Mauvoisin dam site.

1 Cofferdam.
2 Storage reservoir.
3 Useful capacity 157 M m³.
4 Max. level 1,950 m above sea
5 Min. level 1,800 m above sea.
6 Collecting tunnel.
7 Access road to gravel pit.
8 Intake.
9 Intake tunnel.
10 Auxiliary bottom discharge.
11 Flood discharge.
12 Grouting gallery.
13 Sluice chamber.
14 Arch dam.
15 Max. height 227m.
16 Protection works against avalanches.
17 Diversion gallery and bottom discharge.
18 Emptying gallery.
19 Access road to dam.
20 Access road to crest of dam.
21 Discharge.
22 Access adit.
23 Workmen's village.
24 New road.

Power house at Ecône, between Riddes and Saxon, equipped at first with three, later five, generating sets driven each by two horizontal-shaft Pelton turbines.

Tail race 1·2 km. long, discharging into Rhône near the Saillon bridge.

Gross head: 1,021 m.

Installed inflow to turbines: 17.25 cu. m. at first, 28·75 cu. m. per sec. when completed.

Maximum capacity: 180,000 kW (four units).

All the projects connected with this scheme were worked out by the Electro-Watt concern, Zürich. (*Bulletin technique de la Suisse Romande*, Vol. 77, No. 22, 3.11.1951, p. 332, 3 pp., 6 ff.)

C.P.119

AIR POWER FOR PIPELINES

The multitude of construction jobs in the petroleum industry make terrific calls upon pneumatic plant. Here, indeed, is a challenge to the ruggedness, efficiency and reliability of CP equipment. Planned and engineered with imagination and experience, it meets the severest tests imposed by jobs of this kind, whether for preparation of sites and pipe-line trenches, or for workshops and maintenance. Wherever pneumatic power is required, CP equipment will do the job well at the lowest cost in the long run. Surely adequate reasons to . . .

CALL IN CONSOLIDATED

CONSOLIDATED PNEUMATIC TOOL CO. LTD. - LONDON & FRASERBURGH

Offices at Glasgow · Newcastle · Manchester · Birmingham · Leeds · Bridgend · Belfast · Dublin · Johannesburg
Bombay · Melbourne · Paris · Rotterdam · Brussels · Milan · and principal cities throughout the world

Essential to the construction of the big jobs

Henderson

AERIAL CABLEWAYS

for Hydro-Electric Schemes

Night and day in all weathers Henderson Aerial Cableways consistently maintain scheduled construction programmes. The speed, economy and efficiency of Henderson Cableways are essential factors in large building, constructional and hydro-electric undertakings. Henderson Cableways were used for the construction of the Dams at Loch Sloy and Glen Shira, North Scotland, Hydro-Electric Board, and various other home and overseas undertakings.

JOHN M. HENDERSON AND COMPANY LIMITED · KING'S WORKS . ABERDEEN Phone 2426

GREATEST FOOTAGE—LEAST FATIGUE

The R.V.240—a rapid-striking drill specially designed for use with Tungsten Carbide bits**—does the drilling, the "Maxleg" does the supporting and the operator escapes fatigue; which is the economical way of using both men and machines. Holes can be drilled in any position (even right down on the ground) and in the hardest rock with the same ease. As to speed, the pneumatic feed of the "Maxleg" ensures not only more accurate but also much faster drilling than is possible by hand.**

The R.V.240-MAXBIT combination used with the "Maxleg", ensures increased efficiency all round.

CLIMAX

CLIMAX ROCK DRILL & ENGINEERING WORKS LTD.

4, Broad Street Place, London, E.C.2. Works: Carn Brea, Cornwall.

33 TOTHILL STREET, WESTMINSTER, LONDON, S.W.1

BRANCHES: MANCHESTER: Century House, St. Peter's Square. GLASGOW: 87 Union Street.
LEEDS: 70 Albion Street. BIRMINGHAM: 90 Hagley Road, Edgbaston. NEWCASTLE-ON-TYNE: 21 Mosley Street.

we don't produce the oil but

—in the production of Oil-Filled Cable—as indeed of all types of cable—the Pirelli-General Cable Works is a *complete* manufacturing unit. As with other raw material used, so with Oil. On delivery it passes immediately into the control of men whose job it is to condition it for one highly specialised purpose—that of cable manufacture. P-G chemists and technicians test the Oil for dielectric strength, power factor and electrical stability. They clarify and degasify it until as processed oil it is again tested before being pumped into pressurized reservoirs for ultimate use in oil-filled cables, joints and accessories—all top-grade products worthy of the name PIRELLI-GENERAL.

33 kV to 330 kV

OIL-FILLED SUPER TENSION CABLE

PIRELLI-GENERAL

MANUFACTURERS OF EVERY KIND OF ELECTRIC CABLE

PIRELLI-GENERAL CABLE WORKS LTD., SOUTHAMPTON. *(An Associate of The General Electric Co., Ltd.)*

OFFICINE ELETTROMECCANICHE

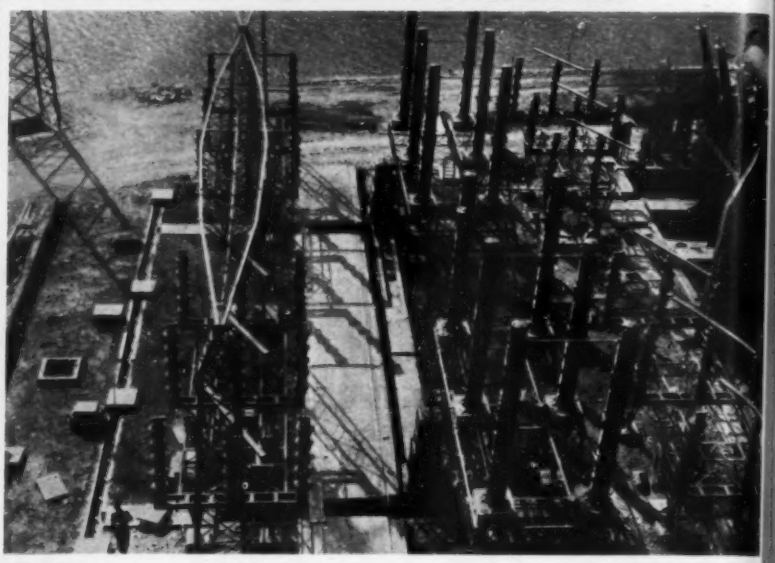
SCARPA & MAGNANO

SAVONA (ITALY)
Via Fiume, 2
CAP. L. 200,000,000
OFFICE IN MILANO
Via Revere, 14
Telegrams : Scarpamagnano

Switchgear:

CIRCUIT BREAKERS
ISOLATING SWITCHES
INSTRUMENT TRANSFORMERS
SWITCHBOARDS, ETC.

FOR BOTH INDOOR AND OUTDOOR SERVICE . . .
FROM **10** UP TO **220 KV**



Low Oil Volume 220 kV, 600 Amps Circuit Breakers Type PO/491, installed in Cedegolo II Power Station of the EDISON Company.

ANDERSON DERRICK CRANES

Two 5-ton Electric Derricks with 130 ft. Jibs on excavations for new reservoir

OUTSTANDING FEATURES

- **"UNIT" GEARING**
- **SUPERIOR VISIBILITY**
- **HIGH SPEED OPERATION**
- **RELIABILITY**
- **ECONOMY**

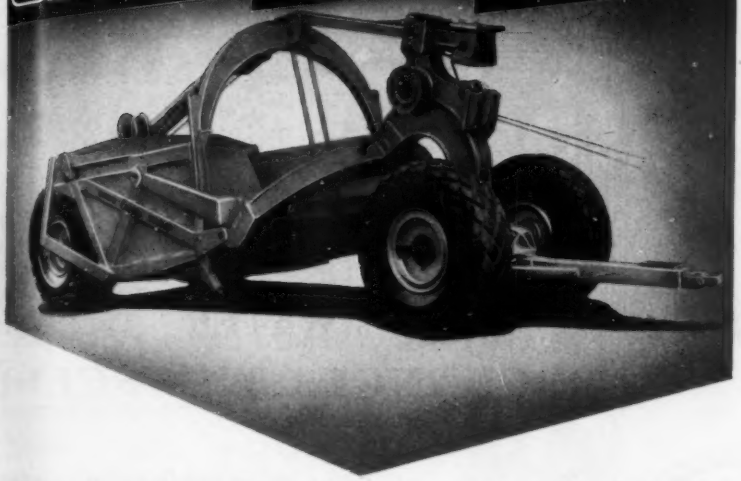
LONDON OFFICE: Finsbury Pavement House, E.C.2. Tel: MONarch 4629

Phone:
CARNOUSTIE
2214-5

THE ANDERSON-GRICE CO. LTD.
TAYMOUTH ENGINEERING WORKS - CARNOUSTIE - SCOTLAND

Grams:
DIAMOND
CARNOUSTIE

ONIONS *Empire* EQUIPMENT

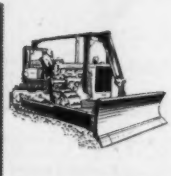


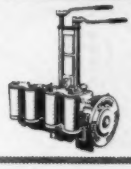
Clears the ground for future progress

For tough going, on tough assignments you need Onions Empire Equipment. Whatever your requirements in earth moving Onions have the equipment to do the job.

ANGLEDOZERS

Rope-operated for large sizes of Caterpillar Fowler International and Allis-Chalmers Tractors.





P. C. Us

Double drumin 3 sizes. Neck groups available for adapting to a very wide range of tractors of all makes.

RIPPERS

Full range to match all sizes of tractors 3 to 5 tines. Weights from 14,000 lbs. to 3,000 lbs.

The 13 cubic yard Scraper illustrated is one of a range of six with capacities varying from 20 cubic yards down to 3½ cubic yards to match all sizes of track type tractors. Special features of this range include low centre of gravity, wide wheel track, Earthmover tyres, positive ejection and spreading by pusher tail gate.

A series of leaflets has been prepared giving detailed specifications of Onions Empire Tractor Equipment for earth-moving. Write for your copies today.

ONIONS & SONS (LEVELLERS) LTD.
BILSTON STAFFS ENGLAND Phone 41751/2/3 Grams SCRAPERS BILSTON

SWITCHGEAR

IVIO

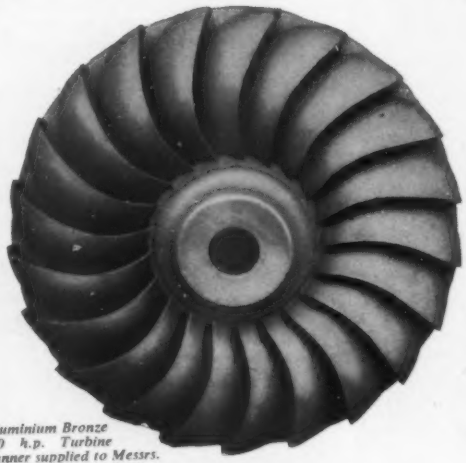
Performance is proved by years of testing in our Climatic Laboratory and confirmed by numerous installations in the most severe tropical areas.

Saving in cost and time of buildings is an additional factor in the increasing popularity of IVIO Outdoor Switchgear.

The equipment illustrated on left was supplied to the Eastern Electricity Board, North Met. Sub. Area, Bishop's Stortford, Herts.

YORKSHIRE SWITCHGEAR & ENGINEERING CO. LTD.
LEEDS and LONDON

ASSOCIATED WITH ELECTRO MECHANICAL MANFG. CO. LTD. : SCARBOROUGH



Aluminium Bronze 180 h.p. Turbine Runner supplied to Messrs. Gilbert Gilkes & Gordon Ltd., of Kendal, England

BIRSO TRADE MARK B&N

HIGH TENSILE

ALUMINIUM BRONZE

CASTINGS

for

WATER POWER INSTALLATIONS

possess a Tensile Strength of 45 tons per sq. in., have a specific gravity of only 7.5 and are guaranteed to withstand any hydraulic pressure; also highly resistant to erosion, corrosion and abrasion.

We are specialists in all kinds of Non-Ferrous Castings — in PHOSPHOR BRONZE, GUN-METAL, MANGANESE BRONZE, ETC. and in Light Alloy Castings, Chill-Cast Phosphor Bronze Rods and Tubes, Precision Machined Parts, etc.

Fully approved by Admiralty and A.I.D.

B104

T. M. BIRKETT & SONS. LTD
HANLEY · STAFFS
'Grams: Birkett, Hanley 'Phone: Stoke-on-Trent 2184-5-6
in association with
BILLINGTON & NEWTON LTD
LONGPORT, STOKE-ON-TRENT
'Grams: Bronze, Phone, Longport 'Phone: Stoke-on-Trent 87303-4 & 88147

WATER CHANGES THE SCENE

The desert can be made to "blossom as the rose" providing adequate water supplies are available—ADSCO have skilled technicians equipped with specialised instruments to carry out geological and geophysical investigations and can supply skilled personnel with up to date drilling rigs for water well drilling. The illustration shews a modern cable percussion rig (Dando '800') lowering in a borehole pump in North Africa.

ADSCO

ASSOCIATED DRILLING & SUPPLY CO. (OVERSEAS) LTD.
IDDESLEIGH HOUSE, CAXTON STREET, LONDON, S.W.1
Telephone: Abbey 3242-3 Cables: Adrillco, London
P115

OVERHEAD HAND POWER CRANES

EXPERTS IN
VAUGHAN
CRANECRAFT

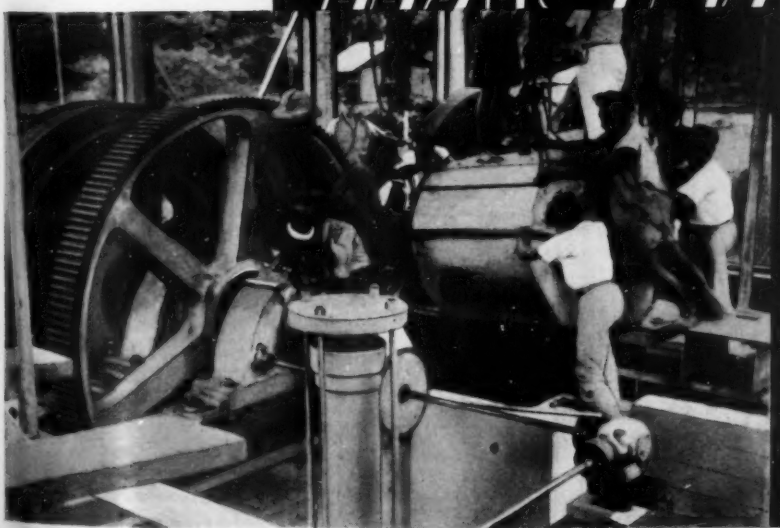
When handling loads by man-power you cannot do better than instal a VAUGHAN Hand Crane. Easy to operate, and inexpensive to maintain, these hard-wearing rugged products still find unlimited uses in modern industry

Made in Single- or Double-Girder Types and in sizes from ½ - 30 tons capacity. Roller bearing runners, high factor of safety, worm geared hoisting motion

THE VAUGHAN CRANE CO. LTD.
WEST GORTON, MANCHESTER 12.
ENGLAND.
Telephone EASt 1473.

Ask for Cat. Section S.G.7. or D.G.5.

EFFICIENT HAULAGE



Hydro-Electrification Scheme—Ceylon

Installation of Haulage Gear at Norton Bridge

M. B. WILD & CO LTD NECHELLS BIRMINGHAM 7
Telephone: EAST 2041-7 Telegrams & Cables: HAULING BIRMINGHAM 7

HYDRO ELECTRIC EQUIPMENT

- HYDRAULIC TURBINES
- BUTTERFLY VALVES
- AIR VALVES
- AIR LOCKS
- PENSTOCKS AND SIPHONS
- SURGE TANKS
- HEAD GATES AND SLUICE GATES
- RADIAL GATES
- STOP LOG HOISTS
- TRASH RACKS AND RAKES
- GANTRY CRANES

◀ HEAD GATES

CANADIAN VICKERS MONTREAL LIMITED
CANADA
Cable Address: VICKERS, MONTREAL.
V-221

Specify MICHELL AND MAKE SURE OF YOUR BEARINGS

THEY 'SET THE COURSE' FOR ENDURING RELIABILITY

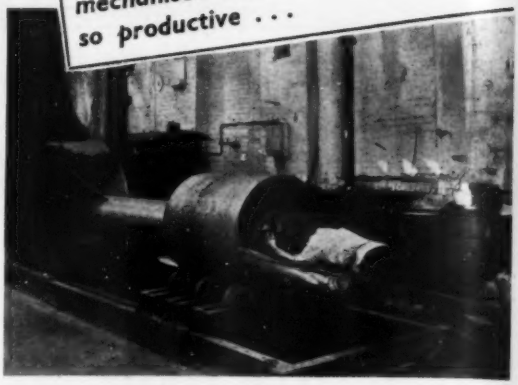
for Hydro Electrical Installations, Turbine Thrusts, Pedestal Bearings, Motors, Generators, Pumps (Vertical and Horizontal), Fans, Paper-Making and Extruding Machines, etc.

MICHELL BEARINGS

SOUTH BENWELL NEWCASTLE upon TYNE

Telegrams: MICHBEARO
Telephone: 34279

IT IS FUSARC-PLANNED EQUIPMENT which makes mechanised welding so productive . . .



INTERNAL WELDING is only one example of a production welding problem solved by Fusarc-planned equipment. There are scores of other examples in a wide field of work, illustrated in Fusarc Production News Sheets, free copies of which will be sent regularly on request.

FUSARC
MECHANISED WELDING

FUSARC LTD., Dept. C. 861, Team Valley, Gateshead-on-Tyne 11

THE RAILWAY GAZETTE
A journal of Railway Management, Engineering, Operation and Railway News.
Prepaid Annual Subscription £4 10s. 0d. *Weekly* 2s.

DIESEL RAILWAY TRACTION
A monthly review of world-wide developments in diesel-engine design and diesel railway traction operation.
Prepaid Annual Subscription 30s. *Monthly* 2s. 6d.

SHIPBUILDING AND SHIPPING RECORD
A journal of Shipbuilding, Marine Engineering, Docks, Harbours and Shipping
Prepaid Annual Subscription £4 10s. 0d. *Weekly* 2s.

POWER AND WORKS ENGINEERING
A practical journal for Plant Owners, Engineers, and Works Managers. *Prepaid Annual Subscription* 35s. *Monthly* 2s. 6d.

NEW COMMONWEALTH
(Incorporating *The Crown Colonist*) describes and illustrates significant developments in production, trade, transportation and related spheres in all countries of the Commonwealth, and provides a unique service of economic information from 50 countries with a total population of 560 millions.
Prepaid Annual Subscription 50s. *Fortnightly* 2s.

COLLIERY ENGINEERING
A practical journal for Colliery Managers and Engineers, and manufacturers of Colliery Equipment.
Prepaid Annual Subscription 35s. *Monthly* 2s. 6d.

COKE AND GAS
A technical journal dealing with the scientific and technical problems involved in the production of coke and gas in coke ovens and gasworks, and the industrial uses of these fuels.
Prepaid Annual Subscription 30s. *Monthly* 2s. 6d.

THE INDUSTRIAL CHEMIST
A journal devoted to the progress of applied Chemistry and Engineering. *Prepaid Annual Subscription* 35s. *Monthly* 2s. 6d.

BUILDING
A practical journal devoted to Architecture and Building Practice.
Prepaid Annual Subscription 35s. *Monthly* 2s. 6d.

WOOD
A practical journal, authoritatively written, superbly illustrated, dealing with the growth, marketing and use of wood in all its forms.
Prepaid Annual Subscription 35s. *Monthly* 2s. 6d.

FOOD
A journal devoted to the manufacture, packing and marketing of processed foodstuffs, and of the utmost value to firms supplying equipment or materials for the food industry.
Prepaid Annual Subscription 35s. *Monthly* 2s. 6d.

WATER POWER
A technical journal devoted to the study of all aspects of Hydro-Electric Development.
Prepaid Annual Subscription 35s. *Monthly* 2s. 6d.

THE RAILWAY MAGAZINE
A popular magazine containing illustrated articles on Railways and Locomotives. Published monthly.
Prepaid Annual Subscription 26s. *Monthly* 2s.

All above published at

33. Tothill Street, Westminster, London, S.W.1

BPC

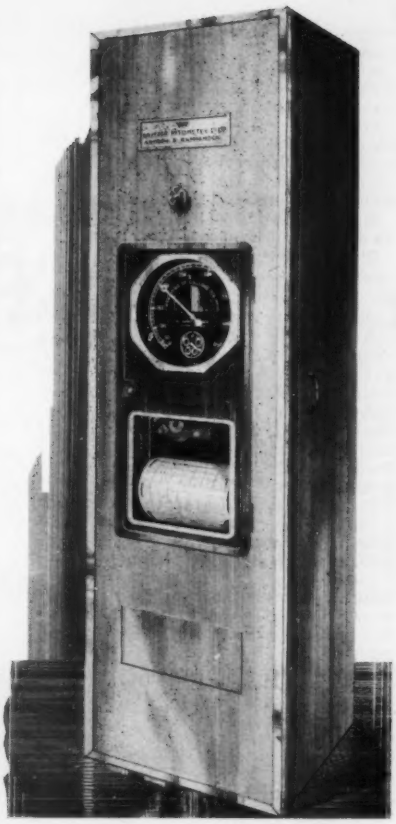
Measuring Equipment
FOR HYDRO-ELECTRIC PLANTS

WATER FLOW
in Tunnels, Pipe Lines and at Turbines.

WATER LEVEL
at Dams and in Surge Shafts for all depths and conditions.

PRESSURE RECORDERS, *ETC.*
backed by over 20 years' experience in this specialised field. can be supplied for local or remote operation.

The illustration shows the type of Flow Meters now being made for the North of Scotland Hydro-electric Board.



The British Pitometer Co. Ltd
(ASSOCIATED WITH GLENFIELD & KENNEDY, LTD.)
105, PARK STREET, LONDON, W.1.

"CORROSION YOUR PROBLEM? Here's *the* Solution!"

A technical advisory service is available to all concerned with the maintenance of iron and steelwork. Send us details of your particular corrosion problem today.

WAILES DOVE BITUMASTIC LTD., HEBBURN, Co. DURHAM. *Telephone:* 32321-5. *Telegrams:* "BITUMASTIC."

INDEX TO ADVERTISEMENTS

A
Allgemeine Elektricitats Gesellschaft —
Allmanna Svenska Electriska Aktiebolaget 19
Anderson-Grice Co. Ltd. 44
Armfield Hydraulic Engineering Co. Ltd., The ... ... —
Arrol, Sir Wm. & Co. Ltd. ... ... —
Associated Drilling & Supply Co. (Overseas) Ltd. 48
Ateliers de Constructions Electriques de Charleroi 4
Ateliers de Constructions Mecaniques de Vevey S.A. ... ... —
Atlas Diesel Co. Ltd. ... 10 & 11

B
Balfour, Beatty & Co. Ltd. ... ... —
Bell, Theodore, Ltd. ... ... —
Billington & Newton Ltd. 46
Birkett, T. M. & Sons Ltd. 46
Blackwood, Hodge, J. & Co. Ltd. ... 26
Blakeborough, J., & Sons Ltd. ... —
Blaw Knox Ltd. 33
Boving & Co. Ltd. 5
Brady, G., & Co. Ltd. 14
British Conway Loaders Ltd. ... 23
British Insulated Callender's Cables Ltd. 38
British Pitometer Co. Ltd. 49
British Ropeway Engineering Co. Ltd. ... ... —
British Thomson-Houston Co. Ltd. 8
Brown Boveri & Co. Ltd. 7
Bruce Peebles & Co. Ltd. 25
Butters Bros. & Co. Ltd. 34

C
Canadian Vickers Ltd. 48
Cementation Co. Ltd., The ... ... —
Ceretti & Tanfani Ropeway Co. Ltd. 27
Christiani & Nielsen 30
Climax Rock Drill & Engineering Works Ltd. 41
Consolidated Pneumatic Tool Co. Ltd. 39
Costain, Richard Ltd. 22
Crompton Parkinson Ltd. ... ... —

D
Dominion Engineering Co. Ltd. ... 6

E
English Electric Co. Ltd. ... *Back Cover*
Escher Wyss Ltd. ... ... —

F
Fabbriche Riunite Cemento ... 12
Ferguson Pailin Ltd. ... ... —
Ferrum (England) Ltd. 9
Fusarc Ltd. 48

G
General Electric Co. Ltd. 29
Gilbert Gilkes & Gordon Ltd. ... 18
Glenfield & Kennedy Ltd. 3

H
Hackbridge & Hewittic Electric Co. Ltd. ... ... —
Harland Engineering Co. Ltd., The 36
Henderson, John M. & Co. Ltd. ... 40
Henley's, W. T., Telegraph Works Co. Ltd. 17
Holman Bros. Ltd. ... *Inside Back Cover*

K
Karlstads Mekaniska Werkstad ... 32

L
Leffel, James & Company, The ... 31

M
Maschinenfabrik Augsburg-Nuernberg A.G. ... ... —
Mechans Ltd. ... ... —
Metropolitan-Vickers Electrical Co. Ltd. ... ... *Front Cover*
Michell Bearings 48
Millars Machinery Co. Ltd. ... —
Morgan, S., Smith, Company ... 15
Morris, Herbert Ltd. 28

N
Newport News Shipbuilding & Dry Dock Co. 35
North of Scotland Hydro-Electric Board ... ... —
Nuttall Edmund Sons & Co. (London) Ltd. ... ... —
Nydqvist & Holm Akt. 24

O
Oerlikon Engineering Company ... —
Onions & Sons (Levellers) Ltd. ... 45

P
Pirelli-General Cable Works Ltd. ... 43
Pyrotenax Ltd. ... ... —

R
Ransomes & Rapier Ltd. ... ... —
Rawlplug Co. Ltd., The ... ... —
Reyrolle, A. & Co. Ltd. *Inside Front Cover*
Riva Costruzioni Meccaniche ... —

S
Scarpa & Magnano 44
Smith, Fredk. & Co. 50
Smith, Thos. & Sons (Rodley) Ltd. 13
South Durham Steel & Iron Co. Ltd. —
Standard Telephones & Cables Ltd. —
Steatite & Porcelain Products Ltd. ... —

T
Taylor, Tunnicliff & Co. Ltd. ... —
Teeside Bridge & Engineering Works Ltd., The ... ... —

V
Vaughan Crane Co. Ltd. 47
Voith, J. M., G.m.b.H. 20

W
Wailes Dove Bitumastic Ltd. ... 49
Watson, Robert & Co. (Constructional Engineers) Ltd. ... ... —
Westinghouse Electric International Company ... ... —
Wild, M. B. & Co. Ltd. 47
Wood, Hugh & Co. Ltd. 16

Y
Yorkshire Electric Transformer Co. Ltd. 21
Yorkshire Switchgear & Engineering Co. Ltd. 45

ANACOS REGD. overhead lines

in

Hard drawn Copper, Cadmium-Copper and Steel cored Aluminium to relevant British Standards.

We are pleased to quote to your specification.

FS & CO

FREDERICK SMITH & COMPANY

ANACONDA WORKS . SALFORD 3 . LANCS.

Incorporated in The London Electric Wire Company and Smiths, Limited
Associated with The Liverpool Electric Cable Co., Ltd. and Vactite Wire Co., Ltd.

LONDON: Published by TOTHILL PRESS LIMITED, Proprietors of WATER POWER, at 33 Tothill Street, Westminster, S.W.1 and Printed by W. & H. SMITH LTD., Evesham, Worcestershire. *January, 1952.*

THE HOLMAN HYDRAULIC DRILRIG

MEANS ECONOMY *Plus*–

Plus **easier drilling:** it drills holes at any angle and in any order in face or walls.

Plus **extra speed:** with long-feed cradles and tungsten carbide tipped Holbits, it cuts the intervals between drilling holes down to seconds.

Plus **extra convenience:** it needs no rigging, roof jacks, columns, staging or spanner work; and is suitable for arched and squared drives. The boom is held stable and true by hydraulic pressure.

Plus **after-sales service** based on a world-wide organisation which makes the advice and assistance of skilled technicians promptly available to all Holman users, wherever they may be.

Single, double or triple boom units supplied. Full details and specifications will be gladly sent on request.

BROS. LTD.
Holman
CAMBORNE . ENGLAND

TELEPHONE: CAMBORNE 2275 (9 LINES) TELEGRAMS: AIRDRILL, CAMBORNE
SUBSIDIARY COMPANIES, BRANCHES & AGENCIES THROUGHOUT THE WORLD HB2

'ENGLISH ELECTRIC'
discharge regulator

Streamline Diffusing Cylindrical Balanced Type

Discharge water from dam outlets possesses considerable energy which, if not regulated, would severely damage the sides of the valley, river bed and concrete structures.

'ENGLISH ELECTRIC' cylindrical balanced discharge regulators destroy this energy by transforming the jet of water into a hollow cone.

The regulator is extremely compact, has simple control gear which can be manually or motor operated, while the balanced closing cylinder ensures that the valve is closed smoothly under all conditions.

'ENGLISH ELECTRIC' discharge regulators have various applications in hydro-electric and irrigation schemes; large numbers are installed and are giving satisfactory service in many parts of the world.

The ENGLISH ELECTRIC Company Limited
QUEENS HOUSE, KINGSWAY, LONDON, W.C.2
Hydro-Electric Department, Stafford
Works: STAFFORD · PRESTON RUGBY · BRADFORD · LIVERPOOL